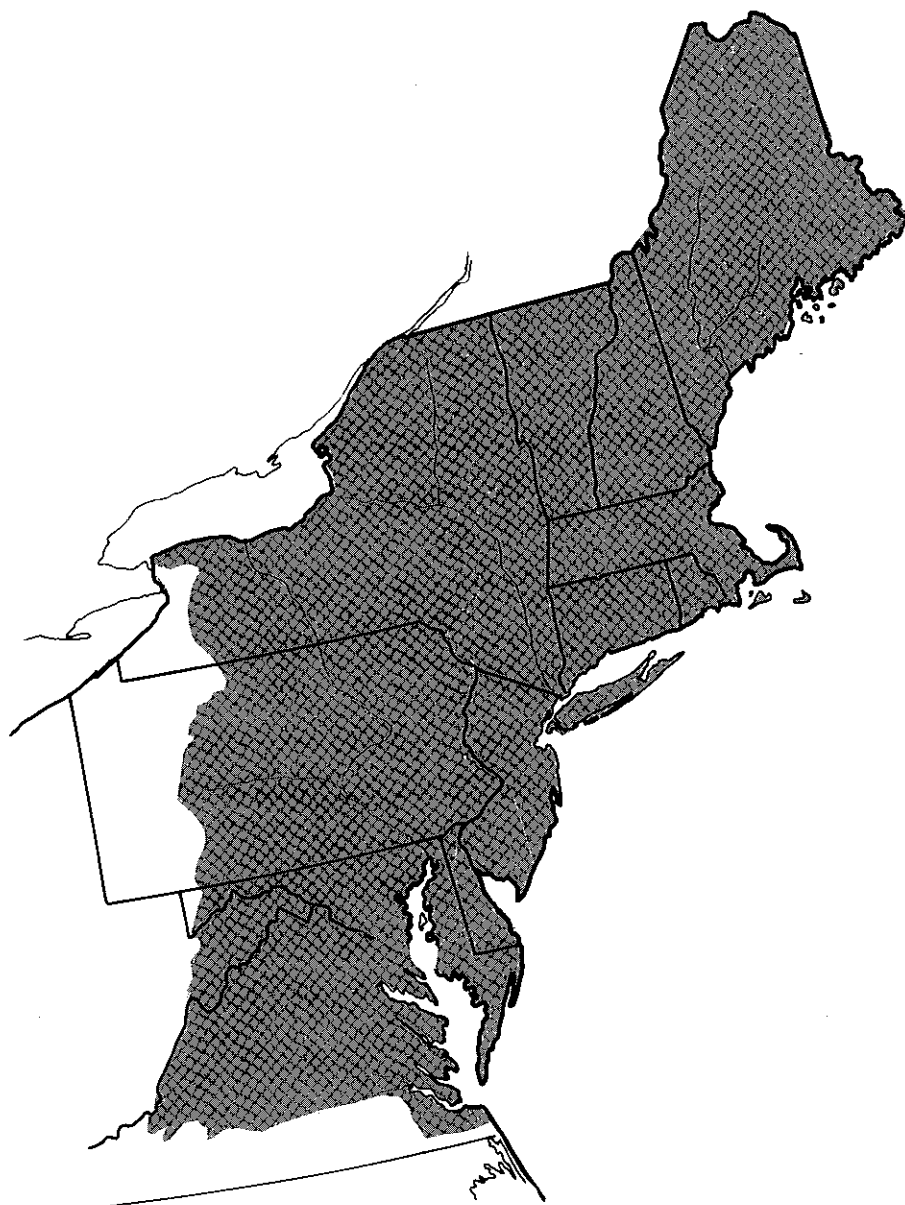


# NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

## INTERIM REPORT CRITICAL CHOICES FOR CRITICAL YEARS

---



TC423  
.1  
.N875  
c.2

---

November 1975

TC423

.1  
.N875

Critical choices for critical years:  
interim report, Northeastern United  
States water supply study / prepared  
by North Atlantic Division, U.S. Army  
Corps of Engineers. -- New York : The  
Division, 1975.  
vi, 89 p. ill. 28 cm. --

c.1 (Northeastern United States water  
c.2 supply (NEWS) study)

"November 1975"

Bibliography: p.81-89.

1. Water-supply--Northeastern States.
2. Water resources development--  
Northeastern States. I. United States.  
Army. Corps of Engineers. North  
Atlantic Division. II. Series

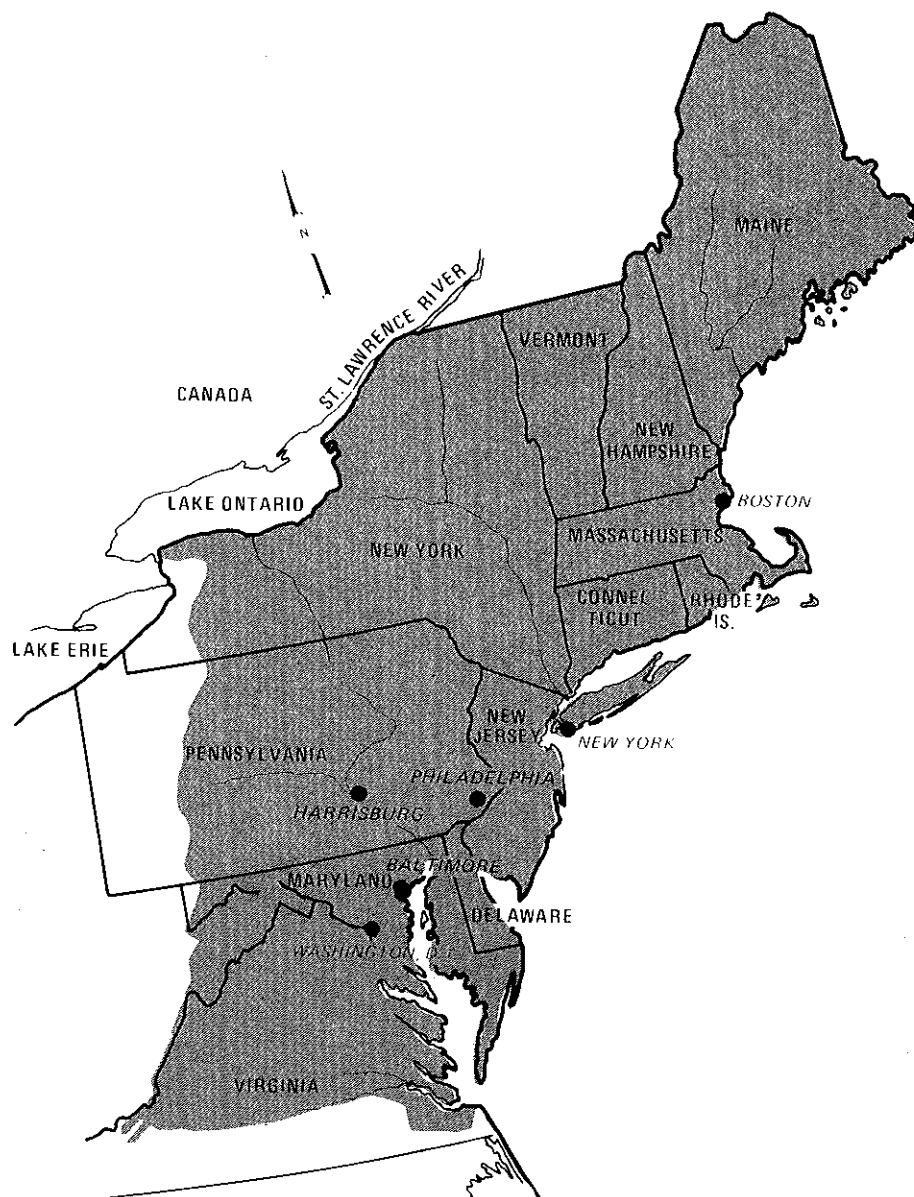
14 OCT 86

2849046 AEEMsl

# NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

## INTERIM REPORT

### CRITICAL CHOICES FOR CRITICAL YEARS



Prepared by  
NORTH ATLANTIC DIVISION  
U.S. ARMY CORPS OF ENGINEERS

November 1975

# TABLE OF CONTENTS

SUMMARIZED CHAPTER CONTENTS	i
INTRODUCTION	v
CHAPTER 1: THE NEWS STUDY	1
CHAPTER 2: THE DEMAND FOR WATER	5
CHAPTER 3: WATER USE REDUCTION	9
CHAPTER 4: SUPPLY INCREASE	11
CHAPTER 5: WATER SUPPLY AND OTHER PLANNING OBJECTIVES	15
CHAPTER 6: THE WASHINGTON METROPOLITAN AREA (WMA)	19
CHAPTER 7: THE NEW YORK METROPOLITAN AREA (NYMA)	39
CHAPTER 8: THE EASTERN MASSACHUSETTS- RHODE ISLAND METROPOLITAN AREA (EMRI)	63
ANNOTATED BIBLIOGRAPHY	81

TABLE	Page	FIGURE	Page	FIGURE	Page
5-1 Energy Requirements for Project Operation	17	2-1 Annual Average Rainfall in New York City 1826-1974	5	6-3 Comparison of Monthly and 7-day Supplies and Demand in 2020	22
6-1 Population, Per Capita Consumption and Average Annual Water Demand Projections -- 1970-2020 - (WMA)	19	2-2 Historic Per Capita Water Consumption - New York City	6	6-4 Decision Timing for Initial Projects - WMA (Phase I)	23
6-2 Potomac River Flows, Demand and Deficits	21	2-3 Percentage Increases of Personal Income, Earnings in Manufac- turing Industries, and Population in the Northeast 1969-2020	7	6-5 Decision Timing for Initial Projects - WMA (Phase II)	23
7-1 Population Projections 1970-2020 - NYMA	39	4-1 Averaged Variations in Water Consumption in New York City - 1971	11	6-6 Decision Tree-WMA Projects	27
7-2 Water Supply Summary- NYMA	40	6-1 Washington Metropolitan Study Area	18	7-1 New York Metropolitan Study Area	38
7-3 Project Implementation Potential - NYMA	47	6-2 Monthly Average Supply and Demand in 2020	22	7-2 Decision Timing for Initial Projects - NYMA	48
8-1 Comparison Between Existing or Projected Demand and Yield - EMRI	64			7-3 Decision Tree-NYMA Projects	51
				8-1 Eastern-Massachusetts - Rhode Island Metropolitan Study Area	62
				8-2 Decision Timing for Initial Projects - EMRI	71
				8-3 Decision Tree-EMRI Projects	73

## SUMMARIZED CHAPTER CONTENTS

### CHAPTER 1

#### THE NEWS STUDY

The severe drought in the Northeastern United States in the 1960's caused the Congress to pass Public Law 89-298 directing the Corps of Engineers to work with appropriate Federal, state and local officials to plan steps to insure against future drought related water shortages in the Northeast.

Studies of the 200,000-square-mile region show that 50 million persons now live in the 13 states and the District of Columbia. Studies also show that by the year 2020, population will increase to 80 million.

Initial findings clearly show that three metropolitan areas, New York, Eastern Massachusetts-Rhode Island, and Washington, D.C., have the most critical and immediate need to develop water supply sources to meet growing water demands.

### CHAPTER 2

#### THE DEMAND FOR WATER

More than 14 million persons living in the Northeast during the 1960's drought, were forced to restrict their water use to conserve dwindling supplies. Many areas came close to running out of water.

Since the drought, no major water supply projects have been built in the three most critical areas. Many water supply systems continue to register average consumption figures that are higher than their safe yields. In 1973 the New York City system had an average consumption that was approx-

imately 170 mgd higher than its safe yield in 1974. The Newark, New Jersey, water supply system supplied 24 mgd more than its safe yield and the system serving Boston delivered 3 mgd above its safe yield in 1973.

The number of people living in an area, their personal income, and the area's industrial growth, all affect total water demand. Projections of these parameters show that water use will continue to grow in these critical areas.

### CHAPTER 3

#### WATER USE REDUCTION

If water supply cannot be increased to meet demand, then demand must be reduced to meet supply. Increasing price to reduce water used in these areas will be effective only if prices are increased by multiples of 100%. The equity of pricing policies would have to be carefully considered.

Temporary use control, during emergencies, can and does work for short periods of time if mandatory water use restrictions are applied. Some temporary reduction can also be obtained by reducing the operation of water using utilities such as power plants. Most use reduction methods are within the jurisdiction of state and local government. Consequently, the ability of these agencies to implement use reduction techniques is a major consideration.

### CHAPTER 4

#### SUPPLY INCREASE

Water availability can be increased through development of a variety of programs. Those available are: system

improvements, surface water, ground water, wastewater and salt water.

#### • System Improvements

Connection of systems to provide joint use of high-flow skimming, ground-water and reservoir storage systems provides many advantages that systems relying on single sources do not possess. Supplies can sometimes be effectively increased through interconnection.

#### • Surface Water

Surface water is the main source of supply in the three critical areas. This can be tapped by the use of on or off stream reservoirs that can supply water directly or can be used to augment stream flows where river intakes are the source. Occasionally suitable sites for small reservoirs can still be found near user areas. Large reservoir sites, however, are generally located away from population centers.

Estuaries could be a source of increased supplies in the New York and Washington, D.C. metropolitan areas. When these estuaries are polluted extensive treatment is required to make the water safe for long-term use.

#### • Ground Water

Ground water is another source of supply. Aquifers can be developed in stages, thereby offering flexibility in meeting changing demands. Ground water recharge areas would have to be monitored closely to prevent pollution.

#### • Wastewater

Wastewater, discharged to streams or aquifers used as water supply sources, makes up a large portion of present

water used. This is found to be a questionable practice. Advanced wastewater treatment plants or carefully controlled land treatment can be employed to make indirect use of wastewater for a completely safe supply. Direct reuse of treated wastewater is not generally considered acceptable.

- **Saltwater**

Desalting is technically feasible, however, environmental and cost problems limit application of this technology.

## **CHAPTER 5**

### **WATER SUPPLY AND OTHER PLANNING OBJECTIVES**

In the three most critical areas, it was found that responsible officials and citizens plan to make their source and project decisions on the basis of factors that go beyond simply increasing supplies to meet demands. These additional considerations range from a project's impact on the environment, its flexibility to meet changing demands and demand patterns, impacts on population growth, cost, and reliability in terms of meeting the demand for water.

In order to facilitate decision making, potential projects for the three most critical areas are arrayed on decision trees with each branch designed to accommodate one or more additional considerations expressed as planning objectives.

It is noted that each source decision, and each possible project, will give rise to questions and criticism from interested citizens and officials. But decisions must be made now if sources are to be tapped and projects completed in time to meet the growing demand and reduce the risk of shortage.

## **CHAPTER 6**

### **THE WASHINGTON METROPOLITAN AREA (WMA)**

#### **Background**

The Corps of Engineers has already recommended the construction of two reservoirs and a pilot estuary water treatment plant to Congress. Additional work, however, will be necessary to meet water supply demands in the area.

#### **Area Profile**

The WMA deserves special consideration because it is the Nation's Capital, a regional center, and because of the magnitude of its water supply problems. The 1970 population of three million is a 39% increase over the 1960 population. Population is expected to total 6.8 million by 2020.

#### **Water Demands**

Water demands are expected to reach 515 mgd by 1980, 720 by the year 2000, and 925 mgd by 2020.

#### **Available Water**

The major source of water in the WMA is the Potomac River. The river flow fluctuates widely around an average flow of 5975 mgd, a fact that must be considered in planning for peak demand periods. Other sources are the Patuxent River, Occoquan Creek and ground water.

#### **Water Supply Programs**

Water supply programs to meet the WMA demands have been formulated to reflect the additional considerations expressed by citizens and agencies, such as reliability, environmental quality, cost, growth control, flexibility and social and economic equity. Sources could be tapped by upstream reservoirs, an estuary treatment plant, local water impoundments, raw water interconnections, ground water and treated wastewater. Demand reduction techniques are also considered. Formulated alternatives are displayed as decision

tree branches and are designed to meet both monthly average and seven (7 through 30) day maximum deficits. A local water saving policy would result in an aggregate total of 45 mgd by 2020 and is included in all branches. Bloomington Dam and Lake will be completed and its 135 mgd available by 1979. It is included in all branches.

#### **Decision Tree**

##### *Branch 1*

Branch 1 contains an array of projects to meet the water supply needs as well as the additional objectives of environmental quality, flexibility, and equity. It includes Bloomington Dam and Lake, ground water, estuary treatment plants and interconnections of existing systems and treated wastewater.

##### *Branch 2*

Branch 2 provides the needed water and includes the additional objectives of environmental quality and growth control through use of Bloomington Dam and Lake and treated wastewater. For 2020, two alternatives, estuary treatment and ground water, are shown.

##### *Branch 3*

Branch 3 provides for the additional objectives of cost, environmental quality, and growth control. It begins with Bloomington Dam and Lake. Treated wastewater, a regional estuary plant, and the imposition of emergency restrictions would meet demands to the year 2010. Ground water is shown for 2020.

##### *Branch 4*

Branch 4 considers reliability, cost and equity. Bloomington would meet water demands to 1980. Subsequently, a local impoundment, and/or interconnections of existing systems, would meet the demand to 2000. Sixes Bridge and Verona Dams are shown for 2020. Restrictions would be employed in the early time frame until additional projects come on line.

### *Branch 5*

Branch 5 reflects the additional objectives of reliability and cost. It, too, begins with Bloomington Dam and Lake. In the years to 2020, it lists Verona and Sixes Bridge Dams and Lakes and local high flow skimming impoundments.

### *Branches 6-8*

Examination of the first five branches have resulted in the formation of three additional branches concentrating on early action. These branches are more fully described in the NEWS – Washington Metropolitan Area Water Supply Study being prepared separately.

## **CHAPTER 7**

### **THE NEW YORK METROPOLITAN AREA (NYMA)**

#### **Background**

The Corps of Engineers has made no specific recommendations to the Congress for the NYMA; however, this report identifies sources of supply and projects for further analysis and discussion.

#### **Area Profile**

The area covers more than 9,000 square miles and includes 26 counties in three states. Water demand ranges geographically from metropolitan New York City to rural areas. Population projections show that the NYMA faces major population increases by the year 2020. Present developed water resources will be totally inadequate to serve the needs of growing population. The population in the area in 1970 was 18.9 million persons. By 2020, more than 26 million persons will live in the area.

#### **Water Demands**

Non-industrial per capita water use in 1970 ranged from 70 to over 200 gallons per day and averaged 185 gpd. Industrial use ranged from almost zero to 50 gpd. Total estimated demand for

water by 2020 will reach 5.1 billion gallons per day.

#### **Available Water**

More than 100 potential projects were studied before the list was narrowed down. Major sources for the area are the Hudson, Delaware, Housatonic, Connecticut, Raritan and Passaic Rivers and ground water in Long Island and Southern New Jersey.

#### **Water Supply Programs**

Programs to meet the growing water demands in the NYMA have been formulated to complement the additional planning objectives that appear to be significant in the area. These include growth control, environmental quality, regional focus, cost, flexibility, and reliability. Although the planning process for the area continues, certain critical choices are emerging and decisions on these must be made now. These include the decision of whether to develop the Delaware or the Hudson first.

#### **Decision Tree**

##### *Branch 1*

Branch 1 provides the needed water at minimum cost. It includes projects that would tap the Raritan River in New Jersey, the Hudson in New York, and the Housatonic in Connecticut, between the years 1980-2000. For 2000 to 2020, the Delaware and Housatonic would be tapped. In 2020, water metering in New York City and further Hudson River development would meet the demands.

##### *Branch 2*

Branch 2 contains projects meeting the additional objectives to water supply of regional focus and environmental quality. It includes development of the Raritan River, ground water and the Housatonic for the 1980-2000 time frame. For 2000-2020, further development of the Housatonic and development of the Hudson would meet the demand for water. For the 2020 demand, the Delaware would be tapped.

##### *Branch 3*

Branch 3 reflects concern for environmental quality and flexibility in addition to water supply. The Raritan, Delaware, Hudson, and Connecticut Rivers would be tapped through diversion or high flow skimming to meet the 1980-2000 demands. Further development of these projects plus water metering in New York City would meet the New Jersey and New York needs through 2020. Connecticut, under this branch, would use the Housatonic.

##### *Branch 4*

This branch presents a program that would meet the water demand while also considering environmental quality and regional focus.

Raritan development and Delaware high flow skimming would meet New Jersey's demand for the first decade. New York would turn to Long Island ground water. For the years 2000-2020, New Jersey would build Two Bridges Reservoir to supplement its share of the high flow skimming of the Hudson, serving both New York and New Jersey. For 2020, further expansion of the Hudson project could supply New York and New Jersey. Connecticut's demands would be met with the Connecticut State Plan. This program also uses metering and total resource management on Long Island to meet 2020 demands.

##### *Branch 5*

Branch 5 contains projects meeting the additional objectives of regional focus and reliability. The Raritan, Delaware, and the Hudson Rivers would be tapped to meet the 1980-2000 demands. For 2000-2020 demands, the gravity development would be expanded for New York and New Jersey, Two Bridges Reservoir would be added to meet additional New Jersey demands, and metering of New York City would be employed. The Connecticut State Plan would supply Connecticut through 2020.

## CHAPTER 8

### THE EASTERN MASSACHUSETTS-RHODE ISLAND METROPOLITAN AREA (EMRI)

#### Background

The most urgent demand for additional water supply in New England is in the Eastern Massachusetts-Rhode Island Metropolitan area. Federal, state, and area officials agreed in 1970 that the Corps should study two projects for diversion of less than 200 mgd from the Connecticut River Basin, investigate the use of the Merrimack River for water supply, and determine the environmental impact of large diversions on the Merrimack and Connecticut River estuaries. Subsequent reports indicate that diversion of 148 mgd would not produce a marked negative environmental impact on the Connecticut River. Project reports have been completed and the Northfield Mountain and Millers River projects recommended as a result for near term needs.

#### Area Profile

The EMRI area consists of Rhode Island and all of Massachusetts except Berkshire County. The region contains 357 municipalities and a population in 1965 of 6.0 million. The population is expected to increase to 9.7 million by 2020. Of the current population, about 85% is urban.

#### Water Demands

Ninety-six percent of the area's population is served by public supply systems. The 1965 area demand was 749 mgd. It is expected to rise to 1287 mgd by 1990 and to 1893 mgd by 2020.

#### Available Water

The major supplier in the area is the Metropolitan District Commission, which served 37% of the 1970 population in Massachusetts. The major potential water source areas are the Connecticut and Merrimack Rivers.

#### Water Supply Programs

Programs to meet the growing water demands have been formulated to also meet the additional objectives that appear to be significant in the area. These include reliability, regional focus, cost, flexibility and environmental quality. Although the planning process is continuing, certain critical choices are emerging and decisions on these must be made now, including the choice of the Connecticut and/or Merrimack Rivers for water supply.

#### Decision Tree

##### *Branch 1*

Branch 1 provides the needed water and reflects the additional objective of reliability. It relies on Connecticut

River diversions for water supply through the 2020 time frame. For 2020, there is a choice of the Connecticut or the Merrimack River or ground water with either River.

##### *Branch 2*

Branch 2 reflects concern for environmental quality and regional focus. For the 1990 time frame, it considers use of the Merrimack River with local ground water, the Big River Dam, and Taunton River highflow skimming.

For the 2000-2020 time frame, alternatives include use of the Merrimack River, regional ground water development, diversions from the Connecticut River, and development of the Nipmuc River and Tarkiln Brook.

##### *Branch 3*

The Branch presents a program which meets the water demand while also considering reliability, regional focus, cost, flexibility and environmental quality. The 1990 demands are met by six projects in Massachusetts and one in Rhode Island, ranging in size from 12-76 mgd. Long term demands would be met by major diversions from the Connecticut and the Merrimack, with the development of smaller reservoirs and the addition of groundwater.

## INTRODUCTION

### Northeastern United States Water Supply — Critical Choices for the Critical Years Ahead

This is an Interim Report on the Northeastern United States Water Supply (NEWS) Study now underway.

The study continues, and a final report will be issued following a series of public meetings and receipt of recommendations from all concerned. However, it is now apparent that problems exist requiring immediate action in the

three most critical areas in the Northeast, the Washington Metropolitan area, the New York Metropolitan area, and the Eastern Massachusetts-Rhode Island Metropolitan area. Critical water shortages exist now and will increase, within the next 20 to 25 years, during periods of less than average rainfall in these areas. Since public works projects normally take many years to plan, authorize, design and build, it is critical that all parties involved in the decision making process be made aware of the choices

available to avert shortages. If a major drought such as occurred in the 1960's reoccurs without further action, there will be shortages. Decisions can be made now, leading to action, to reduce the risk of shortage after 1980.

The purpose of this Interim Report is to present briefly a wide range of available alternatives based on other NEWS studies and to obtain open public discussion and guidance regarding future water supply in the Northeast.



Public Law 89-298  
89th Congress, S. 2300  
October 27, 1965

### An Act

Authorizing the construction, repair, and preservation of certain public works on rivers and harbors for navigation, flood control, and for other purposes.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,*

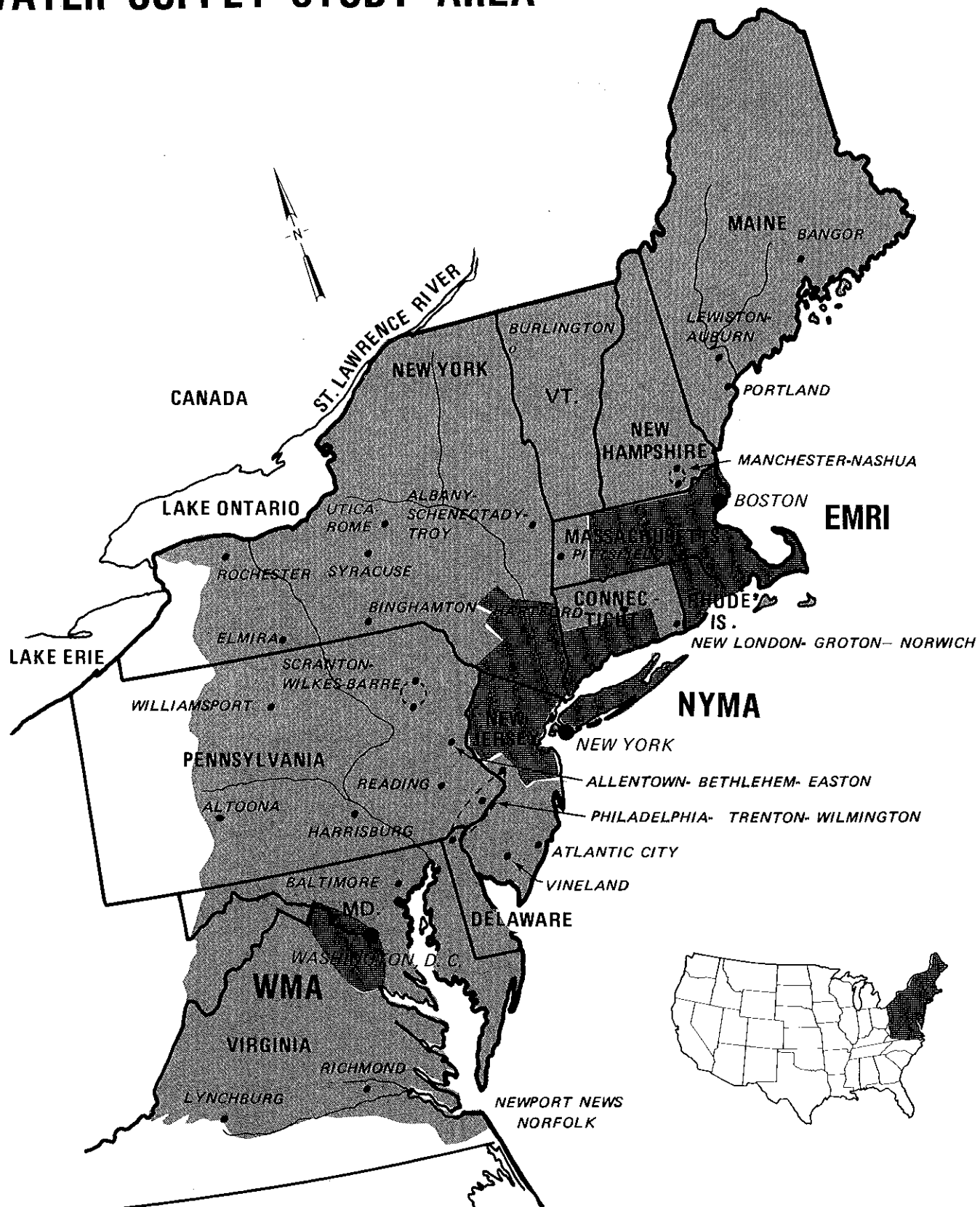
#### TITLE I—NORTHEASTERN UNITED STATES WATER SUPPLY

SEC. 101. (a) Congress hereby recognizes that assuring adequate supplies of water for the great metropolitan centers of the United States has become a problem of such magnitude that the welfare and prosperity of this country require the Federal Government to assist in the solution of water supply problems. Therefore, the Secretary of the Army, acting through the Chief of Engineers, is authorized to cooperate with Federal, State, and local agencies in preparing plans in accordance with the Water Resources Planning Act (Public Law 89-80) to meet the long-range water needs of the northeastern United States. This plan may provide for the construction, operation, and maintenance by the United States of (1) a system of major reservoirs to be located within those river basins of the Northeastern United States which drain into the Chesapeake Bay, those that drain into the Atlantic Ocean north of the Chesapeake Bay, those that drain into Lake Ontario, and those that drain into the Saint Lawrence River, (2) major conveyance facilities by which water may be exchanged between these river basins to the extent found desirable in the national interest, and (3) major purification facilities. Such plans shall provide for appropriate financial participation by the States, political subdivisions thereof, and other local interests.

(b) The Secretary of the Army, acting through the Chief of Engineers, shall construct, operate, and maintain those reservoirs, conveyance facilities, and purification facilities, which are recommended in the plan prepared in accordance with subsection (a) of this section, and which are specifically authorized by law enacted after the date of enactment of this Act.

(c) Each reservoir included in the plan authorized by this section shall be considered as a component of a comprehensive plan for the optimum development of the river basin in which it is situated, as well as a component of the plan established in accordance with this section.

# NORTHEASTERN UNITED STATES WATER SUPPLY STUDY AREA



The United States is blessed with vast natural resources that have fostered and supported its growth, high standard of living, and development into a major world power. Water is among the foremost of the resources upon which our economy and our civilization depends.

Throughout the early phases of our history, there was little competition for water sources. Choices concerning projects to develop sources, the quantity to be supplied, alternative uses and the effects of different uses were much simpler. However, as population has grown additional water sources have been tapped and competition between users has greatly increased. This competition has precluded decisions to develop sources for water supply in time to avert shortages in the event of another major drought. As a result, water shortages are now emerging in urban areas, particularly in the Northeastern United States where about a quarter of our total population is crowded into only about eight percent of the nation's land. The drought of the early 1960's drew attention to this problem and caused the Congress to take action.

That action, in 1965, was the enactment of Section 101, of Public Law 89-298 which states that the problem of assuring adequate supplies of water in metropolitan areas is one that affects the welfare and prosperity of the entire country. The Congress recognized that the problem is of such magnitude and importance in the Northeastern United States that Federal effort is necessary to help solve it. The Congress therefore directed the Corps of Engineers to cooperate with appropriate Federal, State and local agencies in preparing

comprehensive plans to insure that adequate water will be available to meet the long-range demands of the people in the Northeast.

Like the problem pointed up by the 1960's drought, the region involved in the Northeastern United States Water Supply (NEWS) Study is a large one. It extends about 1,000 miles from Northern Maine to Southern Virginia, averaging 200 miles inland from the Atlantic Coast. It involves nearly 200,000 square miles of land, populated in 1970 by about 50 million persons in the states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, the District of Columbia and portions of New York, Pennsylvania, Maryland, West Virginia and Virginia.

By the year 2020, the population in this region probably will have grown to 80 million. Like the present population, it will be concentrated in the five major metropolitan areas of Boston, New York, Philadelphia, Baltimore and Washington. About 60% of the present population already lives in these areas. Since urbanization is a continuing process, the portion of the region's population living in and around these urban centers will in all probability continue to increase.

### Purpose

The purpose of this report is to describe the work done in the NEWS Study to resolve the water supply problems in the three most critical areas. The report displays the major alternative sources of water supply available, together with their advantages and disadvantages, so that the public and governmental agencies may hold responsible discussions and make

knowledgeable decisions regarding future water supply for Northeast. Additionally, the report provides in the Annotated Bibliography, a summary of information developed on the less critical areas.

### The Critical Areas

The authorizing legislation for the NEWS Study directs attention to the water supply problems of metropolitan areas. The classification of Standard Metropolitan Statistical Areas (SMSA) used by the Bureau of the Census was adopted as the mechanism for identifying those areas that would be studied under NEWS. On the basis of preliminary population projections, thirty-one urban areas were identified as containing all current and emerging SMSA's in the Northeast. The water sources and water supply facilities serving these areas were examined to estimate the amounts of water that could be delivered to each area's population and industry during a drought. Population projections were then made and translated into future water supply demands for publicly supplied municipal and industrial water. The projections extended to the year 2020.

Comparison of each area's water supply demand with water supply capability led to an identification of those areas with an immediate near term need (prior to 1990) for increased supply capability, and those with longer range needs. Immediate needs were noted initially for the following five areas:

- Eastern Massachusetts-Rhode Island
- Northern New Jersey-New York City-Western Connecticut
- South Central Pennsylvania
- Baltimore
- Washington, D.C.

As studies progressed, it became apparent that the problems in the South Central Pennsylvania and Baltimore areas were not as urgent as originally thought. Therefore, since this report deals only with the urban areas presently projected to experience near term problems, the South Central Pennsylvania and Baltimore areas have not been included.

Information on the detailed studies made of the South Central Pennsylvania Area is contained in separate reports referenced in the Annotated Bibliography. Detailed studies were not made of the Baltimore area because adequate information had been developed in local studies.

A number of separate studies and reports have been completed for each of the three remaining areas which are considered most critical since they have near term problems. These studies form the basis for this report and are completely listed in the Annotated Bibliography. They range from examination of social, economic and environmental costs and benefits to new technologies, demand reduction and hydrologic analysis. Objectives which could be attained by different water supply projects were identified, leading to the presentation of water supply alternatives by planning objectives in this report.

The twenty-six other urban areas with potential long range problems have been studied to determine demands and supply capabilities. The information is available as a separate report, as referenced in the Annotated Bibliography.

### The Planning Process

Planning for such a large and complex region requires careful and orderly analysis. To accomplish this a series of planning steps has been applied to each area studied. The initial two steps were required for all areas and the remaining steps for the three most critical areas. There are a total of six steps; they are:

1. Examination of the Problem. The first step in the planning process was an examination of the problem. Projected water demands were compared with available supplies throughout the region to determine those areas where potential shortages exist. Those areas having a potential for critical shortages prior to 1990 were identified.
2. Development of Solutions. Technically feasible alternative solutions were developed for all areas and alternative solutions consistent with the individual areas' broad planning objectives were developed for the three most critical areas and for South Central Pennsylvania.
3. Identification of critical Implementation Factors. An examination of the key effects due to implementation of each type of project was made to select the projects having the most positive impacts with respect to achieving different sets of objectives. Where the key effects were sensitive to modification of certain project features, modifications were made to obtain the greatest positive impact, so that projects could be grouped into regional programs best satisfying different sets of objectives.
4. Display of Cash Flow. A financial sensitivity analysis was done to present the flow of money over time for each water supply program. Cash flow over time for each major water user for the cost sharing alternatives being considered in the NEWS Study has been developed.
5. Timing of Decisions. The timing of decisions necessary to insure implementation of early action projects in time to prevent antici-

pated water supply shortages was determined.

6. Determination of Acceptability. NEWS studies have been discussed and reviewed by various groups in the NEWS area. This process has helped to determine acceptability of plans to date. Review of this report is another significant step towards determining which, if any, of the technically feasible solutions are acceptable and compatible with public desires and the plans of the elected and appointed officials of each area. The results of this step will have a major impact on the recommendations in the final NEWS report.

Solutions have been subjected to four key tests during the planning process. They are:

*Reliability:* The ability to assure adequate quantity and quality of water supplies during conditions of severe drought.

*Flexibility:* The capability of being altered to efficiently accommodate future changes in projected water supply demands, and economic, environmental, social and technological considerations.

*Timeliness:* The capability of being implemented in time to meet water supply and other needs and to provide for orderly development of projects to meet additional water supply demands in the future.

*Equity:* The ability to provide for the equitable distribution of natural resources and distribute in a reasonable and logical manner the economic, social and environmental costs of providing adequate water supplies, as well as to compensate equitably those who relinquish water or land rights to meet the water demands of others.

### Planning Premises

As study and planning for the three most critical areas progressed, a number of basic general premises were developed based on data and evidence collected by the Corps of Engineers and other Federal, state and local agencies. Those relevant to this report are:

- The net effects of continued population and economic growth will be to create correspondingly greater demands for water supply, only slightly

offset by increased use of water saving fixtures and appliances.

- Direct reuse of wastewater will not be generally acceptable during the time frame of this study, but water supplies will be significantly increased by deliberate indirect wastewater reuse, for instance, by returning treated wastewater to surface and ground water sources of supply.

- There will be no changes in the ownership of existing water supply utilities.

- Droughts will continue to occur periodically and public demands for water will be met.

- Demands cannot be materially reduced through legislation or changes in water use habits prior to the mid-1990's. Prices would have to be increased to several times current levels to appreciably reduce demand.

Water is such a readily available resource that it is generally taken for granted. To the average person, water is like air — something that is simply there to be used routinely for any purpose and in any quantity necessary. Its abundance is so taken for granted that it appears in a cliché: Free spenders are said to “spend money like it’s water.”

Not until water becomes scarce, or temporarily unavailable, does the individual realize how dependent he is on water in his everyday life.

Health, sanitation, and personal cleanliness all depend on water. Business and industries employing millions of workers, and providing goods and services for additional millions, could not function without plentiful water for manufacturing processes and cooling. The urban and suburban environment, with its treasured green spaces, parks, lawns, and gardens, would suffer if man did not supplement nature’s rainfall. Municipal health and safety services such as street cleaning and fire fighting could not exist without adequate water.

When water becomes scarce during droughts, almost everyone suffers economic losses, as well as reductions in standards of living. This is especially true in large metropolitan areas where the problem is magnified by large populations and complex organizational authorities involved in water supply.

Unfortunately, droughts, like heat waves, are natural weather events that reoccur at random intervals through the years. A study of New York rainfall records shows a history of droughts as well as excesses (see Figure 2-1). These records are an example of

periodic rainfall deficiencies throughout the Northeast. Although much of the Northeast has enjoyed a period of excess rainfall in recent years, it is certain that rainfall deficiencies will occur in the three most critical areas at intervals in the future.

The drought in the Northeast during the early 1960’s presented a classic example of the ramifications of a water shortage. Water supplies dwindled and drastic emergency measures had to be taken to husband remaining

supplies. More than 14 million of the 50 million persons living in the Northeast were restricted in their water use and suffered personal discomfort, inconvenience and economic disturbance. Figure 2-2 shows a reduction in per capita water consumption in New York of approximately 15% during the 1960’s drought and similar reduction during other droughts. This pattern of reduction is fairly typical of the per capita consumption curves displayed by other areas. It can also be noted that per capita consumption quickly returns to or exceeds the long

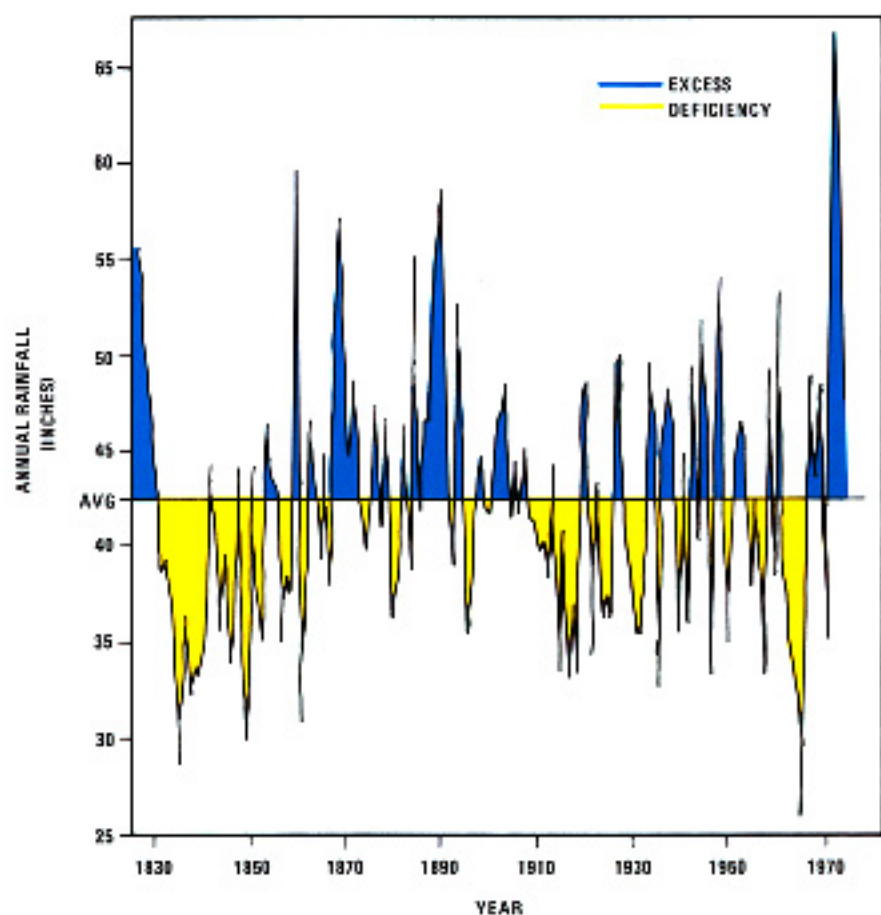
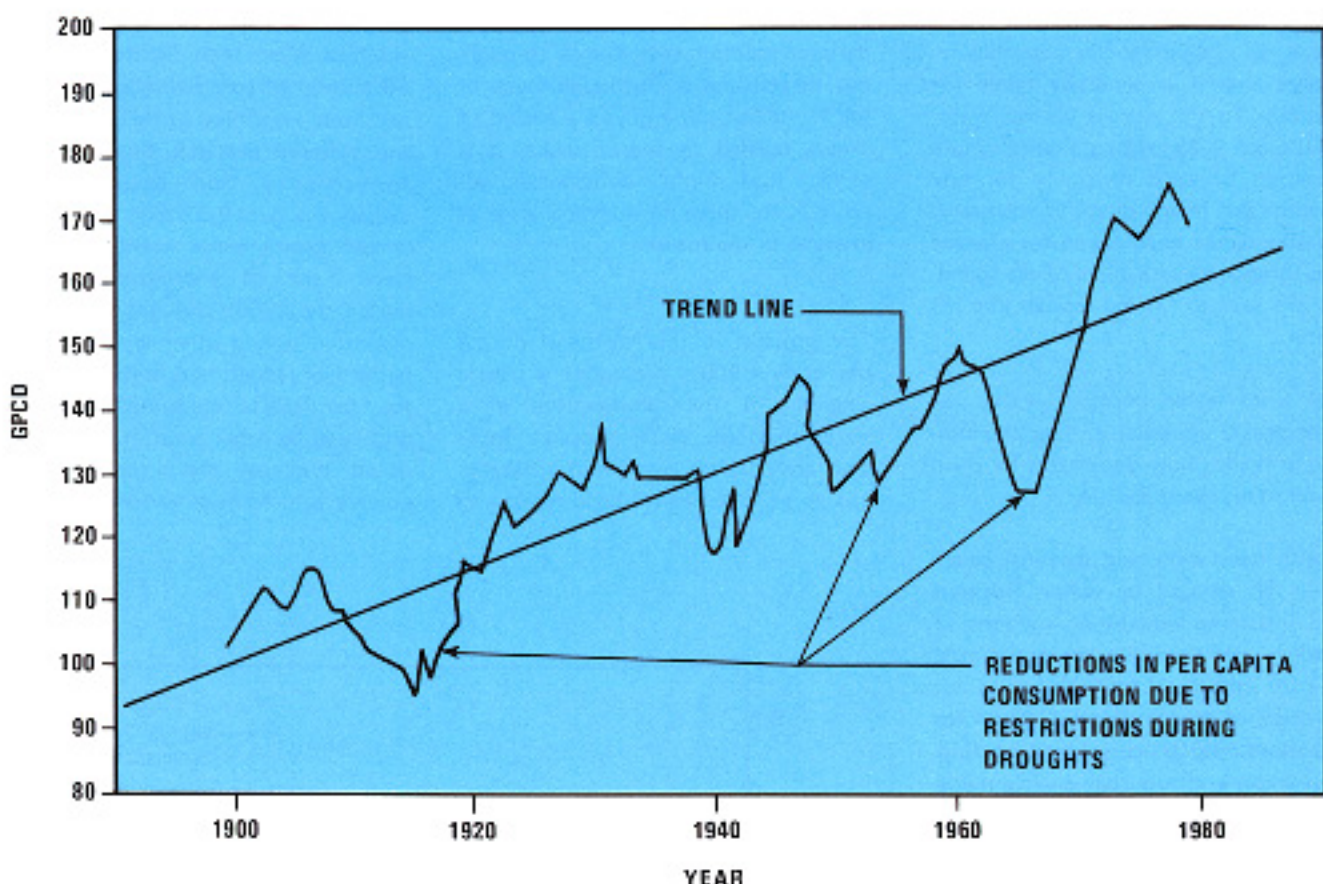


FIGURE 2-1. ANNUAL AVERAGE RAINFALL IN NEW YORK CITY 1826-1974



**FIGURE 2-2. HISTORIC PER CAPITA WATER CONSUMPTION — NEW YORK CITY**

term trend line showing a slight rate (% gpcd/yr) of increase over time. Even with rigidly enforced restrictions, many urban centers came dangerously close to running completely out of water during the 1960's drought.

Since the drought ended in the middle 1960's, no major water supply projects have been built to serve the three most critical areas. Many water systems in the three most critical areas today find themselves routinely supplying more water than they could in a drought. For instance, the New York City system has a safe yield, or drought-time capacity, of 1310 mgd. Yet in 1973 the average consumption was

1,480 mgd.

In Northern New Jersey, the Hackensack Water Company has a safe yield of 82 mgd. Its 1973 average consumption was 89 mgd. The Newark Water Supply System in 1974 saw consumption reach 74 mgd., a full 24 mgd above its safe yield of 50 mgd.

In the Washington, D.C. Metropolitan Area in 1974, nearly 448 mgd. were used from the Potomac River while during the summer of 1966, the flow of the River dropped to a rate of 342 mgd as measured at Point of Rocks.

The Metropolitan District Commission in Boston in 1973 delivered an average

303 mgd with a system that has a safe yield of only 300 mgd.

The number of people living in the three most critical areas, their personal income, and the region's industrial growth have a marked effect on the total water used. The relationship between these parameters in the three most critical areas and the amounts of water used in these areas was studied in order to estimate future per capita water use. The Office of Business Economics of the U.S. Department of Commerce has projected growth in population, income and earnings in manufacturing industries for the entire Northeast [see Figure 2-3]. Moderate or conservative estimates of popu-

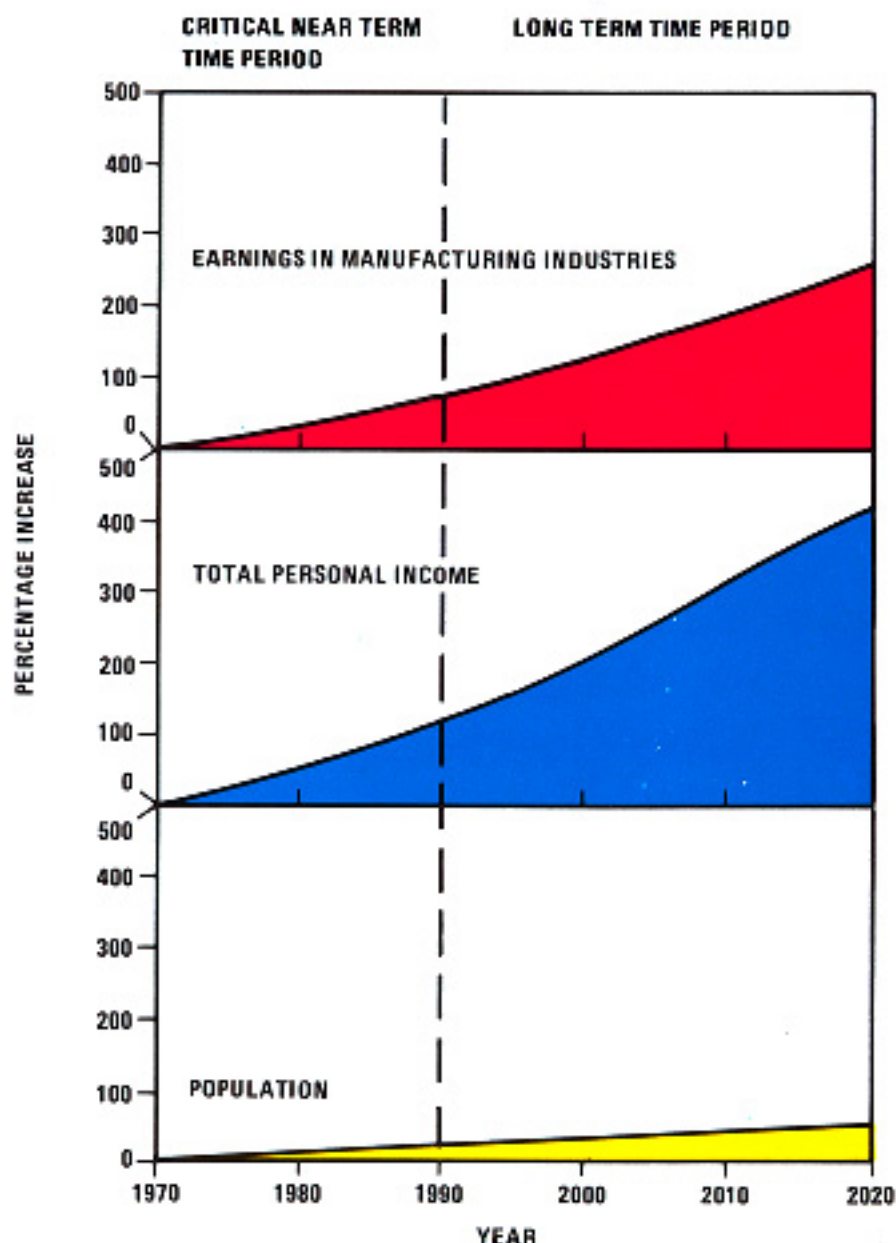
lation growth and per capita water demands were selected. The results of this study indicate that water use will continue to increase at a rate commensurate with the growth reflected in these projections.

It would seem that if growth could be abated by not supplying additional water no new solutions for water supply would be necessary. Unfortunately, growth generally occurs with little attention given to water available

under drought conditions. Developers and the general public appear to be optimists regarding water supply and continue growth based on normal or non-drought year supplies. Many utilities, consequently, maintain service during normal or wet years that could not be sustained under drought conditions.

NEWS studies based on moderate growth and use projections indicate that the gap between available supply

and water use even in non-drought years is narrowing perceptibly. Thus, the impact of the next drought affecting the three most critical areas will be felt far more harshly than the 1960's drought. The cushion between safe yield and use was thin then; it is gone now. Not only is the population growing, but it is using even more water per capita now than in the 1960's because of the growing domestic and industrial investment in water using, work saving devices.



**FIGURE 2-3 PERCENTAGE INCREASES OF PERSONAL INCOME, EARNINGS IN MANUFACTURING INDUSTRIES, AND POPULATION IN THE NORTHEAST - 1969-2020**

## CHAPTER 3: WATER USE REDUCTION

When supply and demand are out of balance, one or the other or both, can usually be adjusted to restore the balance. Such would appear to be the case with water supply and demand. When the population demands more water than is available, then either the supply must be increased to meet the demand or water use must be equitably reduced to the level of available supply. Neither step is easy to implement, but both were investigated.

### Permanent Use Control

Restoring the supply-demand balance by controlling use would appear to be a satisfactory long term solution to a water shortage problem. There is, however, no proven technique for implementing this step. Long term use control has never been attempted in this country. As noted earlier, water is depended on as an integral part of everyday life. The economic, social and political effects of a major long term use restriction would make it both unattractive and unenforceable. In addition, the equitability of applying restrictions to one region and not another would have to be carefully considered.

Although NEWS projections reflect as much as a 250 percent increase in industrial recirculation in critical areas, some additional savings can be obtained through state and local authorities requiring improved industrial recycling or through massive conservation education programs. These are, however, sometimes difficult to implement since industries may leave an area if forced to costlier processes or modernizations, or the public may not be willing to change habits in any but drought years. In addition, industrial demands are not a large part of total

demand in the Washington and Boston areas.

Small permanent reductions in demand are attainable through improvements in water using equipment and processes. Such water economies can be encouraged in new facilities or incorporated during rebuilding or refurbishing of existing domestic, commercial and industrial facilities. Since the cost of installing water saving fixtures is high in existing structures, it is likely to occur only in new or renovated structures, and not in existing facilities.

Institutions exist on the local level to carry out permanent demand reduction through the adoption of new plumbing codes and changes in water metering and rate setting. However, no agencies exist to force the changes in living styles that would be necessary to achieve a large and enduring use reduction.

Institutions also exist at the local level to control growth through zoning or taxation. It is unlikely that these authorities could be applied throughout any of the three most critical areas because of overlapping jurisdictions. If applied in one small locality growth would be shifted to another nearby locality resulting in similar overall demands for the critical area.

Manipulating the price of water could be effective in reducing overall demand. However, to have a significant effect the price would have to be increased not by 100%, but by multiples of 100%. At such price levels, the question of equity would have to be considered. Why should water use be manipulated by this technique when other basic commodities or services for the most part are not? It has broad

implications concerning windfall profits, tax structure, the possibility of discriminating against less affluent segments of the population, or certain geographic areas. The ability to implement a demand reduction oriented pricing policy covering both public and private utilities as well as diverse political jurisdictions remains a problem. Whether this technique can be fairly and justly applied to water supply is a question that will have to be answered in investigations beyond the scope of this study. And until it is, pricing as a means of reducing or limiting use on a permanent basis will remain an unproven and highly questionable technique.

### Temporary Use Control

In emergency or crisis situations, a temporary reduction of 10% to 25% in peak daily use can be accomplished through either voluntary or mandatory restrictions. This technique of reducing water use can be readily employed, but only succeeds when a real emergency exists and people are willing to make sacrifices to meet the emergency.

Voluntary restrictions normally result in smaller reductions than mandatory restrictions. However, neither method is considered likely to produce enduring major reductions in water use.

Time restrictions would include prohibitions on certain water uses during certain hours, thus reducing peak use to more manageable levels.

Use related restrictions involve outright prohibitions of such water uses as lawn or garden watering, washing of cars or streets, operation of ornamental fountains not fitted with recirculating devices, filling of swimming pools

and use of air conditioners with once through water cooling.

Some temporary reduction in water use might also be obtained by reducing the operation of water using utilities. For instance, if restrictions were placed on the use of electricity, portions of power plants needing large amounts of cooling water could be shut down.

Whatever the method or methods selected, they must be reliable if they are to successfully reduce water use.

Water restriction drills during periods of normal water availability could be considered a necessity. In addition, restrictions should affect all consumers equitably, and institutional arrangements must provide for rapid and certain enforcement of use restrictions.

### **Summary**

If the four key tests mentioned in Chapter 1 are applied to the concept of reducing water use, this proposal is not without problems. Use reduction

is not known to be reliable for long periods, since it has not been tried. Neither permanent nor temporary reductions can be instituted in a timely manner without the full and immediate public cooperation that comes from practice. Neither offers flexibility — the use of water cannot be turned on and off at will without creating severe economic, political and social shock. Moreover, it is difficult to be completely equitable to all water users when applying restrictions.

If the use of water cannot be curtailed sufficiently to balance the supply-demand equation, then the only possible alternative is to increase the supplies available. The Northeastern United States is blessed with abundant undeveloped water resources capable of being developed to provide adequate water to meet demand. However, the competition between users has delayed critical development. The available sources are: System Improvements, Surface Water, Groundwater, Wastewater and Salt water.

In considering which sources of water should be employed and which methods used to develop those sources, it should be kept in mind that water use is cyclical. Figure 4-1 shows the variations in water use for New York City over the course of a year. Water use varies even more sharply from hour to hour, and day to day.

Cyclical use is an important element when establishing the design basis for projects and programs to meet water demands in the future. Reservoirs, for example, have large storage volumes and can meet short term peak demands even though their design is primarily to meet average demands over a long period of time. Conversely, water systems that draw directly from a river must be designed so they can meet short term, peak demands, since there is no storage or reserve upon which to draw.

#### System Improvements

One of the fastest ways to increase available supplies, using existing systems is by interconnecting those systems to assist in balancing short term peak demands. Pipelines and pumping stations at key points can then shift water between systems and thus better use in-system storage. Significant in-

creases in yield can be made when interconnected systems include one with a reservoir and another with a large stream available for high flow skimming. When two or more systems having these features are connected, each can depend substantially on the high flow skimming equipment when river flow is sufficient, then each can switch to the reservoir when natural stream flow is low.

The pumping stations and pipeline or tunnel systems needed to shift water in an interconnected system are likely to be large and expensive. However, because interconnection can be accomplished using existing systems and through existing institutions, this method of increasing supply can be implemented more quickly than new sources can be developed.

If interconnection is not feasible, new sources of water supply must be developed. The major new sources of water for each of the three most critical areas are surface and ground water, treated wastewater and salt water.

These sources can be developed by using reservoirs, river intakes, wells, wastewater renovation plants or desalting plants.

#### Surface Water

Surface water can be developed as needed with river intakes, or it can be impounded in reservoirs for later use. Reservoirs vary widely in size, use and location. They can be used to store water for direct use via pipeline or tunnel or to augment stream flows for increased down stream use. High flow skimming, water from a stream pumped into an off stream reservoir, is also frequently employed.

The location and size of reservoirs are generally dictated by a combination of topography and urban development. Suitable sites for small reservoirs can occasionally still be found in or near the metropolitan centers they would serve. Large reservoirs, however, must be located away from highly populated metropolitan areas because few lightly populated and topographically suitable sites remain in those areas.

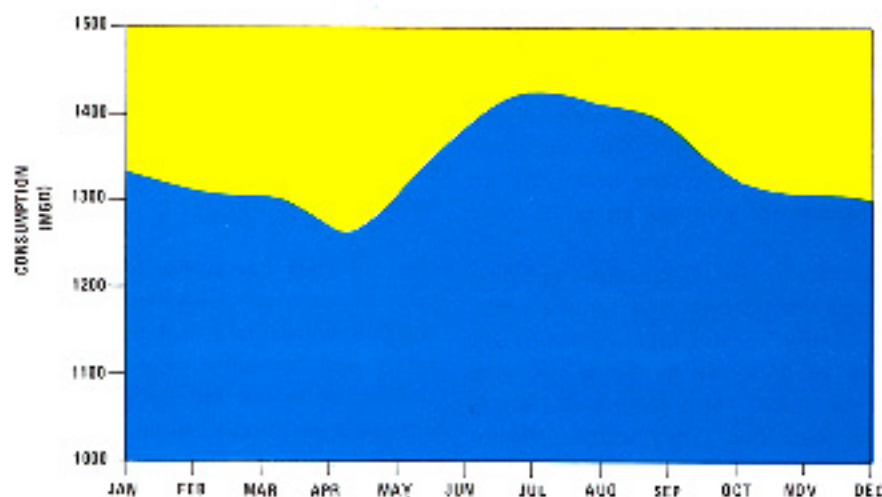


FIGURE 4-1. AVERAGED VARIATIONS IN WATER CONSUMPTION IN NEW YORK CITY - 1971

Large reservoirs create complications that have nothing to do with the design or yield of a reservoir, but rather involve controversies between political jurisdictions and institutions. Usually these jurisdictional questions can be solved only by the intervention of the state or Federal Government which must decide whether water users in one river basin can go beyond their political boundaries and into another area or watershed to get water. Settling jurisdictional disputes, of course, often takes years.

When a large reservoir project involves the transfer of water from one major river basin to another, the effects on both donor and receiver areas must be carefully evaluated. Obviously, taking water from a river basin will have an effect on the basin. The additional water in the receiving basin will also have an effect on that basin's rivers. Consideration must be given to both beneficial and adverse consequences associated with major alterations to stream flows in both basins.

In summary then, small reservoirs, if they can be located close to the users, can often be built fairly quickly without major jurisdictional complication. Their individual safe yield, (amount of withdrawal that can be sustained during the design drought) however, is necessarily small. Large reservoirs, because of their size and because they usually must be built away from the user area, take a correspondingly longer time to build. They do, however, provide a supply which will be adequate for a longer period of time.

One source of controversy regarding reservoirs is their land requirements. Generally, several small reservoirs are not as efficient in terms of land requirements for a given safe yield as one large one. They usually require more land area to obtain an equivalent storage volume. Just as 100 store owners can band together and build a shopping center on less land than it

would take if each of them built on a separate plot with a separate parking lot and access road, so can a large reservoir impound more water using less land than many small reservoirs.

The tidal lower reaches of rivers, or estuaries, are often overlooked as sources of water supply. The freshwater portions of estuaries, (the upper sections not containing significant amounts of salt) are potential sources of water for coastal metropolitan areas such as Washington and New York. These are, unfortunately, often grossly polluted by untreated or poorly treated wastewater discharges and storm water runoff.

With the accelerated abatement of water pollution mandated by the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), estuaries may become useful sources of additional supply in the future.

Estuaries can be used before the zero pollution mandate by Congress becomes effective, by withdrawing the water and treating it in conventional water treatment plants before putting it into a distribution system. Because conventional treatment plants are not designed to treat water that is as highly polluted as may be found in many estuaries, this method involves certain public health risks. It may be acceptable to live with those risks for limited periods of time in an emergency, but not for longer periods. This method, however, may be implemented in a fairly short period of time by existing institutions.

The Congress has authorized a large pilot or prototype treatment plant on the Potomac estuary to determine the safety and feasibility of a variety of techniques to use estuary water as a potable water supply source.

#### **Ground Water**

The second major source of additional water supply is ground water. Large

ground water sources exist near some metropolitan areas lying in the coastal plains of the Northeast. Well fields to tap such aquifers are technically feasible and can be built as needed. A typical system will normally include pumps at the well heads, chlorination equipment, pipelines to distribute the water and perhaps small reservoirs and pumping stations along the distribution line.

Large amounts of energy must be provided to run the pumps, and back-up power systems, such as diesel-fuel generators, must be built to provide power for the pumps in case of electrical failure.

Although ground water development offers speed and efficiency of construction, it also has drawbacks. Ground water may be the property of the owner of the land over it. Before ground water can be withdrawn, individual property rights must be considered, since withdrawal of large quantities of water from an aquifer may cause other wells in the aquifer to go dry. Major legal complications can arise in such cases.

Ground water development also requires the protection of the aquifer recharge areas. Since aquifers often flow under the surface for many miles, it is possible that contaminants entering the ground water miles away could flow through the aquifer to the well field, thus contaminating the well water.

#### **Waste Water**

Another source of additional water that can be used to meet increasing demands in the three most critical areas is treated wastewater.

Indirect wastewater reuse is neither new or unusual. It is not unusual for one community to dump partially treated or even untreated wastewater into a river that is used as a source of water supply by downstream com-

munities. Neither is it unusual for communities to rely heavily on ground water as a source of supply while at the same time relying on septic tanks or cesspools for wastewater disposal. The effluent from such disposal systems is only partially purified before entering the aquifers that provide water supply.

The dilution of wastewater dumped into a river, the chemical and biological reactions that take place as the water travels downstream, and the filtering of septic tank effluent through layers of soil, provide some natural purification. This treatment is, however, haphazard and does not guarantee that the water is entirely safe to use. The fact that more public health problems have not resulted from this practice is due more to good luck than to good planning.

Indirect use of wastewater can be made safe by employing carefully controlled and planned methods such as advanced wastewater treatment (AWT) plants or land treatment of wastewater.

AWT plants whether using biological or chemical-physical processes, can produce effluent that is eminently suitable for indirect water supply use. The effluent from an AWT plant can be safely discharged into a stream or surface water body that is used as a water supply source. While the emphasis and interest in AWT plants has in the past centered on their role as a pollution control tool, their usefulness as a viable source of water supply cannot be overlooked.

Land treatment is another method of indirectly using wastewater for water supply. In this method, treated wastewater is applied on the land in an even and controlled manner, and the land itself becomes a treatment and filtering medium. Thus the groundwater is recharged with clean water. This method requires substantial tracts of suitable land that may be very costly



**TREATED WASTEWATER USED  
FOR SPRAY IRRIGATION**

and require extensive periods of time to acquire. Land treatment can also be a means to complement land use planning objectives by providing open green space and improving agricultural yields through its irrigation and fertilization benefits.

While deliberate indirect reuse of wastewater may be possible in a short time, direct reuse is another matter. Direct reuse, that is, putting treated wastewater directly into a water supply system, involves the construction of AWT plants to treat wastewater to such a high degree of purity that it would be potable.

Direct use of AWT effluent has not been practiced in this country and is barely advanced beyond the experimental pilot plant stage here. One city in South Africa, however, has used AWT effluent as a direct source of water supply, but the method cannot yet be accepted as fully proven for general application.

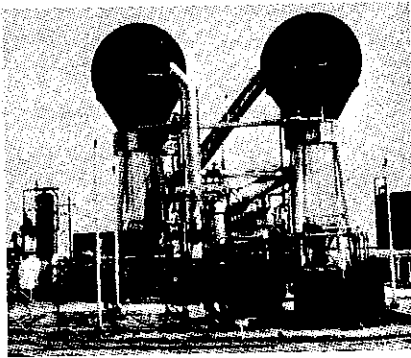
Virus contamination and build up of dissolved solids present problems in dealing with direct reuse. Also, since the AWT plant would be connected directly with the water supply system, there would be no time lag in which to

detect and correct any malfunction in the treatment process. Therefore, the highest degree of reliability is required. Until these problems, as well as opposition because of the general attitude toward direct reuse are overcome, this method of water supply must be deferred to the somewhat distant future.

### **Salt Water**

The final potential source of additional water to meet growing needs is salt water. Desalting is a technically feasible option, but its application is limited by both energy demands and the high costs of building and running such a plant. Desalting plants are large industrial complexes that can be expected to run the gauntlet of social and aesthetic problems usually associated with large industrial installations. Desalting also produces large quantities of a waste product, hot brine, that must be disposed of in an acceptable manner.

Existing institutional and legal frameworks can generally implement this method to increase supplies, especially in areas where coastal industrial complexes already exist. However, the high cost and relatively exotic nature of



**DESALTING PLANT**

this technology probably preclude its quick implementation. Desalting is expensive in comparison with other sources of potable water.

#### **Safe Yield**

The safe yield of a water supply system is that amount of fresh water, expressed as a rate of flow, that can be continuously supplied during a specified drought. The worst drought of record is being used as the basis for planning in the NEWS Study, and in most sections of the northeast this is the drought of the early 1960's. Safe yield can be increased by providing storage in manmade reservoirs or developed from the natural storage areas of lakes, aquifers and estuaries. Yield can also be developed from water which is immediately at hand flowing by in a river or from converted wastewater and saltwater.

Safe yield for each new supply source is briefly defined as follows:

*Systems Improvements* — Safe yield is the expected incremental amount of supply improvement under drought conditions expressed as a rate of flow.

*Surface Water* — Safe yield is the lowest natural streamflow supplemented by storage releases that can be maintained continuously for the duration of the design drought. Safe yield may be limited by the size of intakes or treatment facilities.

*Groundwater* — Safe yield is the maximum draft that could be continuously supplied by pumping on a long term basis during a drought. It is theoretically the natural recharge less losses and outflows from the aquifer.

*Wastewater* — Safe yield is the amount of the source available, less losses in the treatment and recovery process.

*Saltwater* — Safe yield is limited only by intake and treatment facilities.

As the demand for water approaches the safe yield of a water supply system, greater efficiency must be used in the day to day operation of an "immediately at hand" system as opposed to operation of a "storage" system. Until a storage system is either empty or almost empty, it can temporarily meet cyclical demands higher than designed for by drawing on stored reserves, since demands will have the tendency to average out during cyclical periods, of lower than average use. This flexibility is not inherent in a system that relies on water immediately at hand. If a river intake, flow or water treatment plant are not large enough, demand simply cannot be met. If this happens, resultant pressure drops can suck contaminants back into the water lines causing public health problems, and random parts of the water system will lose fire fighting capability.

The New York and Eastern Massachusetts-Rhode Island Metropolitan areas rely heavily on providing safe yield through storage, while the Washington Metropolitan Area relies primarily on water immediately at hand in the Potomac River. Water supply programs for the Washington Metropolitan Area, therefore, must be able to deal with short duration peak deficits during a drought as well as with the longer term overall deficit that develops for an entire drought period. The water supply programs for the Washington Area shown in chapter 6 are therefore

based on deficits both for a long term drought period over 30 days, and short term peak deficits for various time periods less than 30 days. On the other hand, programs for the New York and Eastern Massachusetts-Rhode Island areas shown in chapters 7 and 8 are based only on deficits for a long term drought period.

#### **Summary**

System improvements, surface, ground, waste and salt water, then, are the sources that can be tapped to increase water supplies to meet demand in the three most critical areas. Each has its drawbacks and its advantages. Some sources are readily accessible, some are distant; some may be developed quickly, others will require long lead times. Some methods are costly, others less expensive. Some methods are proven, others need more work to resolve their technological problems.

Each source, each method, will have its opponents and supporters, but if the demand for water is to be met in the three most critical areas of the Northeast, each and every source and method must be weighed against the consequences of not meeting that demand.

## CHAPTER 5: WATER SUPPLY AND OTHER PLANNING OBJECTIVES

Water is so important to our standard of living, the population is so dependent on it, that any decision involving water attracts attention from considerable numbers of people. Each person who becomes involved in the decision making process, no matter how informally, brings with him a slightly different viewpoint on which important considerations must be taken into account in that decision making process. These apparently conflicting viewpoints are often differences in emphasis only. For instance, one person may feel that the cost of a water supply project should be the determining factor in decision making. Another may agree that cost is important, but that the most vital consideration should be the reliability of the project to meet demands, and so forth.

In other cases, the difference of opinion over what should be the determining factor in selecting a source of additional supply, or a method for tapping that source, is sharp and apparently not reconcilable. A person who thinks cost should be the determining factor may face a head-on collision with another who feels that environmental quality should be the determining factor, regardless of the cost.

Such differences of opinion over what should be key factors in decision making must be considered in drawing up alternative solutions to water supply problems. It is presumed, as stated earlier, that the water supply demands of the three most critical areas will be met, but to present solutions that simply meet that goal conveniently or expeditiously, or in the most technologically feasible manner, would be to ignore the additional considerations that figure prom-

inently in local decision makers' thinking.

In discussing the NEWS Study work with individuals in the three most critical areas, some uniformity of additional considerations was found. Most local officials mentioned low risk, limited cost, environmental impact, control of growth, self sufficiency and a regional focus as being vital considerations that officials and interested citizens would like to consider while meeting water supply demands. These additional considerations have been adopted as planning objectives for designing the water supply programs presented in subsequent chapters. They are defined as follows:

1. *Reliability*: the ability to assure adequate quantity and quality of water supplies during conditions of severe drought.
2. *Flexibility*: the capability of being altered to efficiently accommodate future changes in projected water supply demands, and economic, environmental, social and technological considerations.
3. *Timeliness*: the capability of being implemented in time to meet water supply and other needs and to provide for orderly development of projects to meet additional water supply demands in the future.
4. *Equity*: the ability to provide for the equitable distribution of natural resources and distribute in a reasonable and logical manner the economic, social and environmental costs of providing adequate water supplies, as well as to compensate equitably those who relinquish water or land

rights to meet the water demands of others.

5. *Cost*: meeting of water demands at the least monetary costs, considering both capital investments and operation and maintenance expenditures.
6. *Environmental Quality*: maintenance or enhancement of existing conditions as a result of the impact of a project.
7. *Regional Focus*: use of water from a single source over as wide an area of need as is efficient.
8. *Growth Control*: tendency of water supply programs or projects to complement local plans to influence the rate and/or distribution of population growth in an area.

Regional programs to meet the water supply demands over time for each of the three most critical areas are presented in this report as different combinations of time phased projects. Each combination of projects will meet the demand for water and is also designed to stress particular local planning objectives. Groups of different local planning objectives are consequently used to typify differences among the alternative regional water supply programs.

### Decision Making

In order to simplify the comparison of different projects and combinations of projects, they are presented in the form of decision trees for each of the three most critical areas. Each branch of each decision tree illustrates one of the possible means to meet the ultimate goal of supplying sufficient water to meet demand, and at the same time

complement or partially satisfy one or more other objectives mentioned by the interested officials and citizens in the area.

It should be noted that, in comparing the programs on decision tree branches, one objective can generally be fully satisfied only at the expense of the others. Projects designed for least cost, for instance, were selected with little regard for their impacts on other objectives such as environmental impact or flexibility. A program to complement those objectives would almost certainly be more costly.

Despite the large numbers of technically feasible projects available in each of the three most critical areas, it is virtually impossible to satisfy all objectives in each area with one water supply program.

Despite this problem, if projects are to be on line in time to avert shortages, choices will have to be made soon.

The next three chapters on this report will present sources, projects and illustrative combinations of projects. No attempt is intended to advocate any particular project or combination of projects, or any sequence in which they should be built. The purpose here is to lay out the various alternatives so that the people of the three most critical areas might more easily see the choice of actions available to them.

As noted earlier, Congress mandated the Corps of Engineers "to cooperate with Federal, state and local agencies in preparing plans . . . to meet the . . . water needs of the Northeastern United States." If these Federal, state and local agencies assist in making choices now it is possible that selected projects or other actions can be consummated in time to avert shortages.

#### **Cost Sharing**

An important consideration for any regional program for water supply

must be the financial and cost sharing arrangements that might be used to bring it into being.

Detailed analyses of the financial and cost sharing arrangements for the various projects and programs developed in the NEWS Study have been performed. When decisions are made they will require information on cash flow over time associated with each plan. The concept of equitable distribution of costs and benefits requires an assessment of value received and portion of costs borne at the local, state and Federal levels. Therefore, an analysis has been completed describing local cash flow for local funding as well as for extra local (state and Federal) funding. The analysis included expenditures for planning, technical research, land acquisition, construction, operation and maintenance, and indirect expenses as well as the flows of revenues required by the various levels of government and private companies, to repay debts or bonds, or to establish funds for future expansions.

Federal participation in water supply, presently limited to reimbursable construction, is under study and re-evaluation, and the precise form of cost-sharing that would be most effective and equitable would depend on the particular program considered. Almost any role assumed by the Federal Government could increase the assurance of future water supply in the Northeast. This role could vary in form from technical assistance to considerable financial assistance.

For purposes of this report two funding assumptions have been developed, local and extra local. Local funding assumed debt service beginning the year construction started with a 35 year pay back period with equal annual amortization. A 6.14% average 1974 municipal bond rate was used. The extra local funding assumed Federal capitalization with debt service beginning when a project is first used

and interest payments beginning 10 years after a project is completed. Equal annual amortization over 50 years at the 4.371% rate set in July 1974 under the 1958 Water Supply Act, was assumed.

#### **Energy**

In view of the recent energy crisis and the critically low generating capacity reserve in much of the Northeast, energy requirements for the operation of projects have been explicitly addressed in this report.

The required connected load and the amount of energy consumed per million gallons of water supplied are presented for each project in a regional program. As a rule, systems which deliver raw water by gravity require less energy than systems which deliver water by extensive water treatment and pumping.

The range of energy requirements for the operation of projects described in this report is shown in Table 5-1.

**TABLE 5-1. ENERGY REQUIREMENTS FOR PROJECT OPERATION**

Type of Project	Connected Load (Kw) <sup>1</sup>	Energy to Supply One Million Gallons of Water (Kwh/mg)
Upstream Reservoir	0	0
Highflow Skimming	4200 - 200,600	10 - 6400
Wells	3300 - 32,080	1600 - 5100
AWT	30000 - 44,000	117,200 - 177,700
Estuarine Plant	9700 - 37,400	2400 - 5,500
Gravity Transmission	0	0
Transmission by Pumping <sup>2</sup>		
24 ft. Tunnel	150 per MGD	3600
8 in. Pipeline	1500 per MGD	36,000

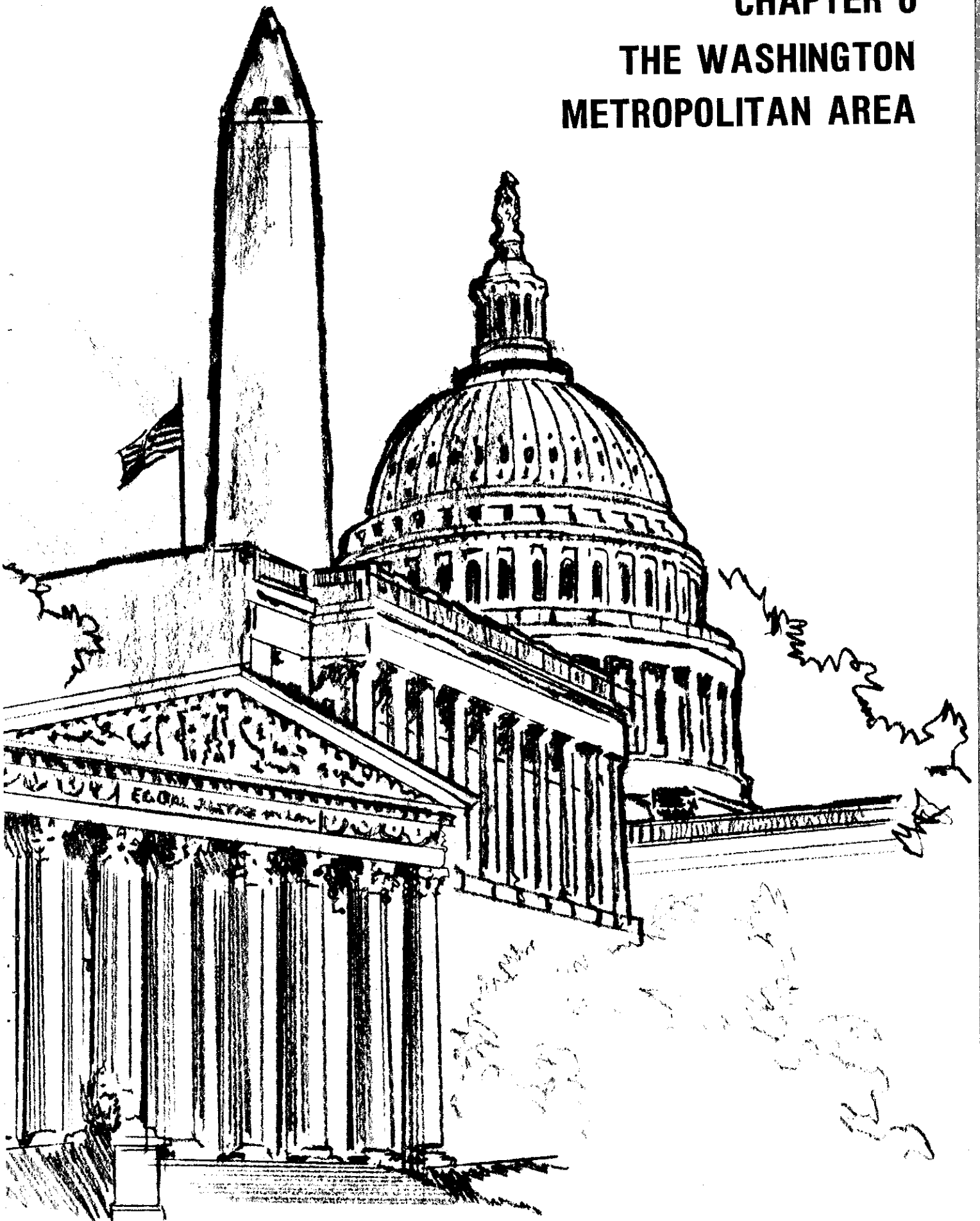
<sup>1</sup> Connected load is the maximum momentary demand for power.

<sup>2</sup> Both the tunnel and pipeline are based on same change in elevation (300 feet) and length of transmission (50 miles).

# CHAPTER 6

## THE WASHINGTON METROPOLITAN AREA

CHAPTER 6 - WASHINGTON  
METROPOLITAN AREA



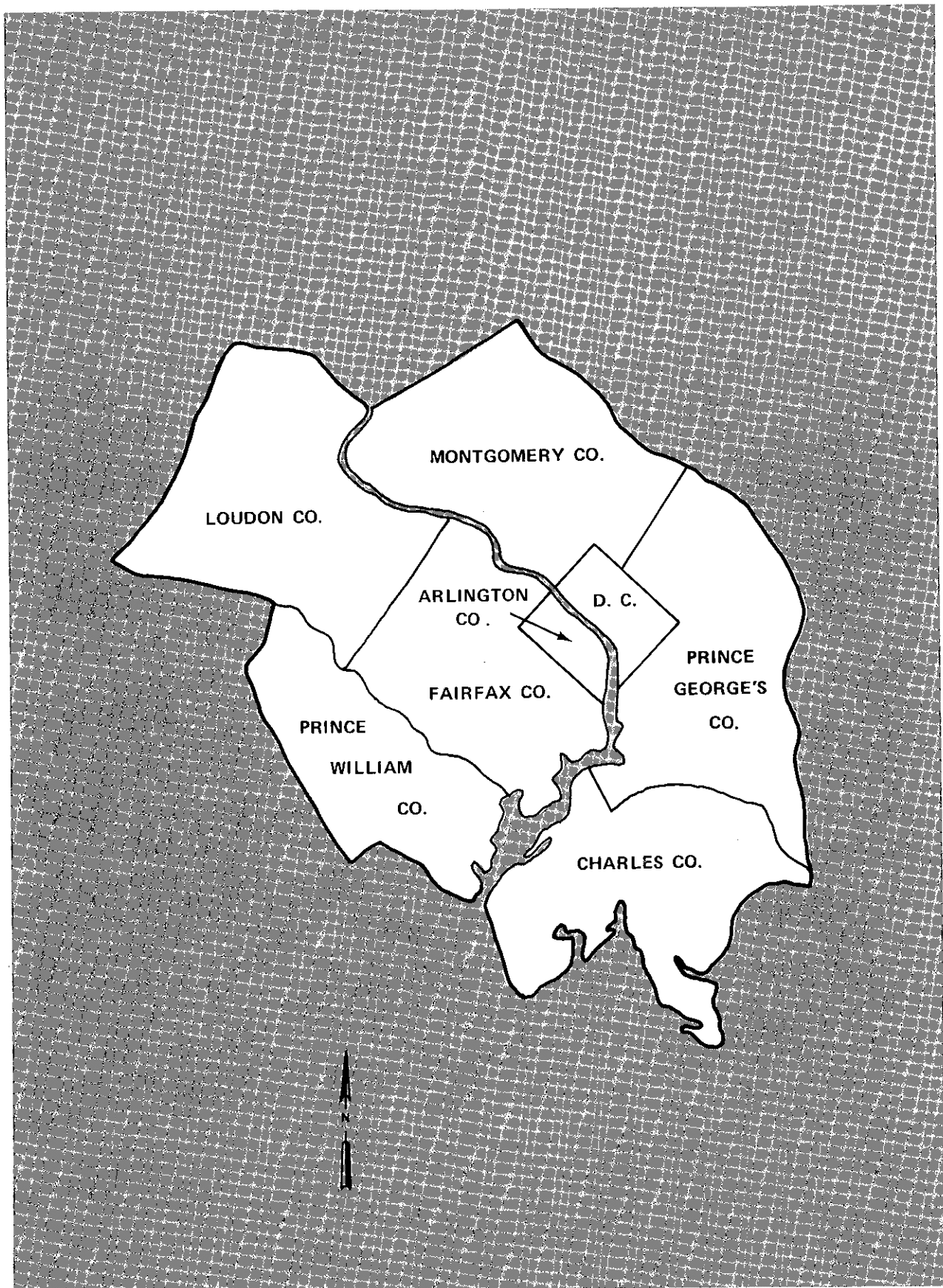


FIGURE 6-1. WASHINGTON METROPOLITAN STUDY AREA

## CHAPTER 6: THE WASHINGTON METROPOLITAN AREA

### BACKGROUND

Recommendations to meet the immediate water supply needs of the Washington Metropolitan Area (WMA) have already been made to the Congress as part of the NEWS Study. The recommendations are contained in a report, *Potomac River Basin Water Supply — An Interim Report*, of April, 1973.

These recommendations are:

- Construction of the Verona Dam and Lake in Virginia and Sixes Bridge Dam and Lake in Maryland to meet the near-term water demands with the proven technique of reservoirs.
- The construction of a pilot estuarine water treatment plant to determine the technical feasibility of full scale use of the estuary for water supply, and to answer the question of public health risk related to use of the estuary.

As a result of these recommendations Public Law 93-251 authorized the construction of the pilot estuarine treatment plant and advanced engineering and design of Verona Dam and Lake and Sixes Bridge Dam and Lake. No further authorization may be made regarding the Sixes Bridge Dam Project prior to completion of the Washington Metropolitan Area Future Water Needs Study also authorized in Public Law 93-251.

These steps and construction of Bloomington Dam and Lake, scheduled for completion in 1979, constitute the first actions to solve the more immediate water supply problems of the WMA. Therefore, this chapter will concentrate on the alternatives available to complete a long-range water supply program.

The alternatives presented in this chapter have been based on a number of other NEWS studies done for the WMA and referenced in the Annotated Bibliography. Much of this work has also been summarized in a previous staff report issued in April, 1974 and circulated in the Washington Area. Recent public feedback and technical studies have provided the basis upon which a further consolidation of these alternatives has been made. This work will provide the basis upon which to initiate the Washington Metropolitan Area Future Water Needs Study.

### AREA PROFILE

The Washington Metropolitan Area lies primarily within the Potomac River Basin with its eastern section in the much smaller Patuxent River Basin. The WMA encompasses land and water in the states of Maryland and Virginia and the District of Columbia. It covers 2800 square miles and consists of Montgomery, Prince George's and Charles Counties in Maryland; the District of Columbia; the Cities of Falls Church, Fairfax, and Alexandria, and

the Counties of Loudon, Fairfax, Prince William and Arlington in Virginia (see Figure 6-1).

The WMA deserves special consideration because it is the Nation's Capital, a regional center, and because of the magnitude of its water supply problems. This area is designated as a Standard Metropolitan Statistical Area (SMSA) for the purposes of census data collection. The 1970 population work of about three million represents a 39 percent increase over the 1960 level and makes Metropolitan Washington the seventh most populous SMSA in the Country. Population projections for the area show 3.7 million persons by 1980, and 6.8 million persons by 2020 (see Table 6-1).

### WATER DEMANDS

Demands for water in the WMA are based on projections, through 1992, by the Metropolitan Washington Council of Governments (COG). They were modified by adding Charles County, extension to 2020 and downward adjustment of 1 mgd a year for water

TABLE 6-1. POPULATION, PER CAPITA CONSUMPTION AND AVERAGE ANNUAL WATER DEMAND PROJECTIONS — 1970 - 2020. (WMA)

	Population Projections (millions)	Per Capita Consumption (gallons/day)		Average Annual Water Demand Projections (mgd)
		Without Water Saving Devices	With Water Saving Devices	
1970 <sup>1</sup>	2.9	134	134	390
1980	3.7	141	139	515 <sup>2</sup>
2000	5.2	142	138	720 <sup>3</sup>
2020	6.8	143	137	925 <sup>4</sup>

1. Actual

2. 350 mgd is Potomac demand and 165 mgd is non-Potomac demand.

3. 545 mgd is Potomac demand and 175 mgd is non-Potomac demand.

4. 740 mgd is Potomac demand and 185 mgd is non-Potomac demand.

#### SOURCE:

Metropolitan Washington Council of Governments, Alternative 6.2, modified, July 16, 1973, (COG forecasts are not official projections and do not represent official policy of COG or its member governments. This information is for study purposes only); linear interpolation and extrapolation for 1980 through 2020, includes Charles County.

saving devices required by local building codes. Resulting regional demands are shown in Table 6-1.

A fairly stable per capita demand for water is expected for the WMA between 1980 and 2020. This is due to two factors: first, little increase is projected for water using industries; second, it is a high income area with a resulting saturation of domestic water-using appliances. Consequently, the increase in per capita use expected in many areas of the country due to increased use of such appliances is not expected in the WMA.

### AVAILABLE WATER

A number of raw drinking water sources were considered for the WMA. However, the costs and legal complications involved with major inter basin transfer projects, such as from the Susquehanna or Rappahanock, indicated that the relatively undeveloped nearby sources should be considered first.

#### Potomac River

The largest single water resource within the Washington Metropolitan Area, the Potomac River, has an average discharge at Point of Rocks of 5,975 mgd. Beginning in the mountains of West Virginia, it flows north in Maryland, and then generally southeasterly toward Washington, D.C., for 248 miles, to Little Falls, Virginia, becoming tidal for 114 miles to its mouth in the Chesapeake Bay.

Due to the natural physical condition of the Basin and relative lack of natural and man-made regulation, flows in the River fluctuate widely around an average of 5,975 mgd as measured at Point of Rocks. The lowest daily flow of record was 342 mgd at Point of Rocks and 388 mgd further downstream at Little Falls. The major share of WMA demands will

be met by water from the Potomac River, although flows from the Patuxent River and Charles County groundwater will also be used. Non-Potomac sources of water for the WMA presently supply approximately 150 mgd and are assumed to increase to 185 mgd by 2020.

The lack of storage in the basin means that the portion of WMA demands being met by river withdrawals is very sensitive to the wide fluctuation of Potomac River flows. This sensitivity is compounded by seasonal variation in demand. If highest demands occur at times of lowest flow, deficits will be large. The alternatives for the WMA have been formulated in such a way that some risk exists if highest demand occurs during times of lowest flow. Historically this has not occurred and public feedback indicates that many individuals in the area are willing to accept this risk.

Demands were projected to vary by month in a fixed way assuming that July would always be the month of highest use. Supply was projected in the same way assuming that lowest flows would always occur in October. On this basis the critical monthly deficit always occurs in August since the difference between supply and demand is the greatest. Monthly maximum 7 day (seven through 30 days) and monthly maximum 1 day periods (one through six days) have been examined to determine critical peak deficits of shorter duration than a month. Since non-Potomac demands can be met from other sources they were removed from the regional demands.

Supply figures were developed from 77 years of Potomac flow records at Point of Rocks, Maryland. The base year used for supply was 1930, since it had the smallest recorded volume of water for the critical five month summer period (July through November).

Other supply assumptions include the availability of water from Bloomington Dam and Lake by 1979 and maintenance of a minimum flow in the River at Little Falls, MD. of 100 mgd at all times.

To explain Table 6-2, if the monthly average demands shown are met, deficits lasting longer than one month will not occur. If the seven day peak demands are supplied, deficits of 7 through 30 days will not occur. It was assumed that peak one day (1 through 6) deficits will be the responsibility of local utilities since the increment over the seven day supply is small, is easily subject to restrictions, and is more readily provided by local systems than regional systems. If needed, part of the 100 mgd of water reserved for flow into the estuary could be used for the one day deficits.

In Figures 6-2 and 6-3, the monthly and seven-day deficits information is shown in graph form for the years noted. The yellow shaded areas represent the additional water needed to meet average monthly demands. The brown shaded area represents the additional water needed to meet the maximum seven day demand occurring in August.

Since NEWS studies show there will be an adequate amount of water in the Potomac in all but the five months of July through November, the programs for the WMA are designed to meet the monthly and seven day water supply deficits for each of these months for any year from 1980 to 2020.

#### Patuxent River

The Patuxent drains 930 square miles in Maryland. Though highly regulated, it has an average flow of 95 mgd at Laurel, Md., which is in the vicinity of the WMA. It begins in the rolling uplands of the Piedmont Plateau and flows southerly for 110 miles through

low-lying swampy flood plains emptying into its estuary, then to its mouth in the Chesapeake Bay.

#### Occoquan Creek

Occoquan Creek is a tributary to the upper Potomac Estuary with a drainage area of 570 square miles. The Creek begins in lower slopes of the Blue Ridge mountains, and flows southeasterly to its mouth. The Occoquan Dam located near the mouth of the Occoquan Creek regulates the stream, assuring a safe yield of 65 mgd.

#### Ground Water

There are two regions within the study area from which ground water supplies are available, the Hagerstown Valley and the Coastal Plains. The range of yields from individual wells varies, but the safe yield of each well field is unknown.

#### Other Factors

Water treatment capability and the capacity of the existing water supply distribution system are two factors that, in addition to safe yield, limit

Washington's water supplies. Existing system capacities will not be adequate for future demands. Expansions, however, have been planned by the major utilities.

#### WATER SUPPLY PROGRAMS

Preliminary alternative water supply programs to meet the WMA demands have been formulated to meet a mix of program objectives chosen to reflect the diversity of values held by individuals and groups in the area. All

TABLE 6-2. POTOMAC RIVER FLOWS, DEMANDS AND DEFICIT<sup>3</sup>

MONTH	PERIOD	1980			2000			2020		
		Demand <sup>1</sup> (MGD)	Flow <sup>2</sup> (MGD)	Deficit (MGD)	Demand <sup>1</sup> (MGD)	Flow <sup>2</sup> (MGD)	Deficit (MGD)	Demand <sup>1</sup> (MGD)	Flow <sup>2</sup> (MGD)	Deficit (MGD)
July	Month	420	670	—	650	670	—	880	670	210
	7-day	450	470	—	695	470	225	940	470	470
	1-day	500	445	55	770	445	325	1040	445	595
Aug.	Month	415	535	—	635	535	100	855	535	320
	7-day	475	485	—	730	485	245	985	485	500
	1-day	530	450	80	815	450	365	1095	450	645
Sept.	Month	390	575	—	605	575	30	815	575	240
	7-day	425	530	—	655	530	125	890	530	360
	1-day	450	495	—	700	495	205	945	495	450
Oct.	Month	350	490	—	545	490	55	735	490	245
	7-day	360	460	—	560	460	100	760	460	300
	1-day	380	435	—	590	435	155	795	435	360
Nov.	Month	335	520	—	515	520	—	700	520	180
	7-day	345	435	—	540	435	105	730	435	295
	1-day	355	415	—	555	415	140	750	415	335

<sup>1</sup> DEMAND — Month figures are monthly averages. A seven day figure is the maximum average demand of any seven (7) consecutive days in the month. A one-day figure is the highest one-day demand that month. Does not include Non-Potomac River demands; includes a one (1) MGD incremental reduction per year due to water saving devices.

<sup>2</sup> FLOW — Month figures are monthly averages. A seven-day figure is the minimum average flow of any seven (7) consecutive days in the month. A one-day figure is the lowest one day flow of that month. Includes Potomac River flows at Point of Rocks, Bloomington Dam and Lake coming on line in 1979, and 100 mgd allocated for flow into the estuary.

<sup>3</sup> Includes that portion of the WMA withdrawing from the Potomac River, presently and in the future.

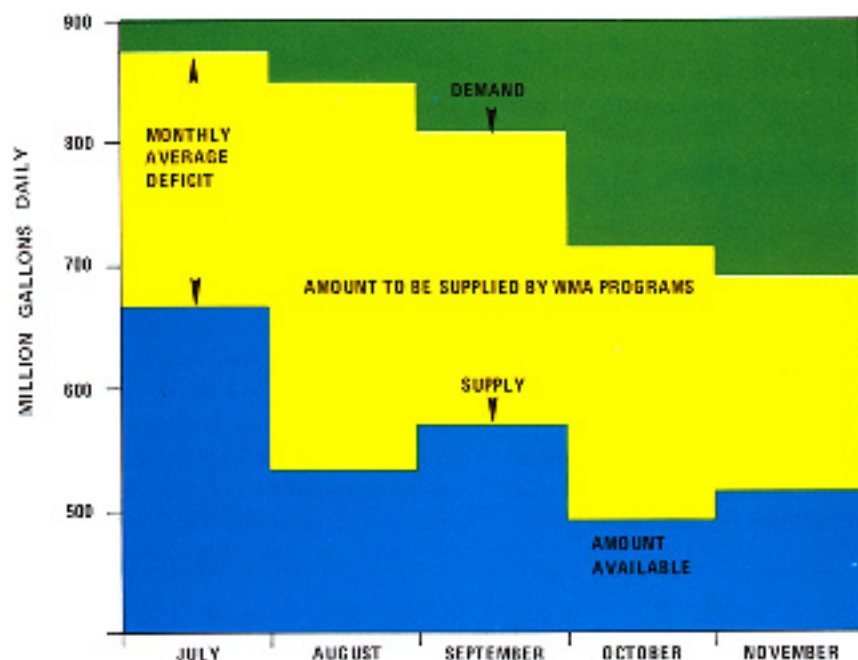


FIGURE 6-2 MONTHLY AVERAGE SUPPLY AND DEMAND IN 2020

risk that deficits would be larger if the highest demand should occur when flows are lowest. During most of the year no additional water is needed even by 2020, but, during the five month period between July and November, deficits could occur regularly by 2020. The month of August was determined to have the largest monthly deficits. As much as possible, the programs were designed to eliminate monthly deficits with monthly or base load projects and seven day deficits with seven day or peaking projects. In some cases projects can be operated for both. Solution of the one (1 through 6) day deficit problem can be more appropriately handled by the local utilities. This approach to program design will supply water to the WMA in the most efficient manner consistent with the planning objectives expressed by many groups in the WMA. The programs have been arranged into decision tree branches for selected combinations of planning objectives. The specification of the timing of decisions required to place water supply projects on line in time to avert shortages is shown in Figure 6-4.

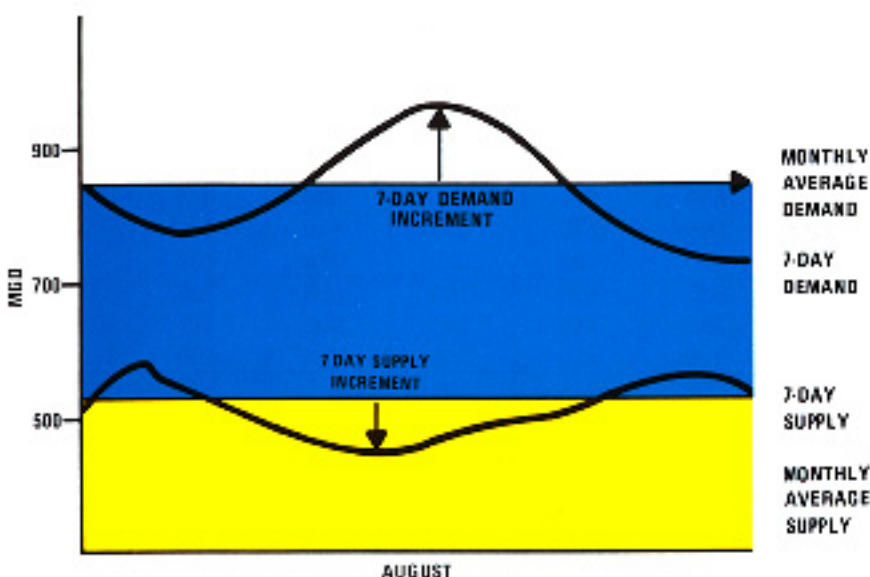


FIGURE 6-3. COMPARISON OF MONTHLY AND 7-DAY SUPPLIES & DEMANDS IN 2020

programs satisfy the fundamental water supply objective, as well as complement the various other local planning objectives.

Recognizing the conflicting uses for water resources, a detailed analysis of

supply and demand was conducted to establish minimum project requirements to satisfy the water supply need. This analysis consists primarily of comparing supply and demand on a month by month basis to determine deficits while accepting the

A critical choice has become apparent during the WMA study. Many of the project alternatives desired by local interests are new or unproven technologies. Before any of these can be implemented, their technical feasibility must be proven. Small scale pilot facilities to evaluate estuary treatment, advanced waste water treatment (AWT) facilities, land treatment and unproven ground water aquifers appear necessary. The pilot tests of these technologies could delay their full scale implementation until 1990. If demand is adjusted to explicitly incorporate conservation programs, Bloomington Dam and Lake can meet the monthly WMA demand through 1990. The seven (7 through 30) day demands cannot be met by Bloomington much beyond 1980. Therefore, a new project must be on line by 1980

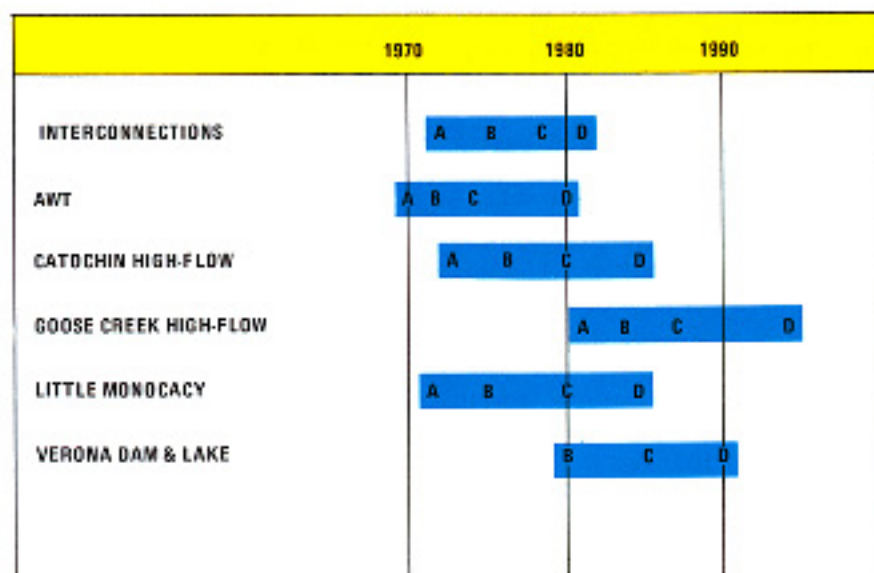
unless the people of the region are willing to accept an increased risk of less than 30-day water supply deficit.

Consequently, a choice that must be faced in the WMA is whether to: 1) Use proven technologies such as raw water interconnections, Verona and Sixes Bridge Dam and Lake and local impoundments; or 2) accept the risk of less than 30-day supply deficits while pilot testing programs of land treatment, estuary treatment, AWT plants, and ground water aquifers.

Based on the reaction to the WMA staff report, key elements of the five Decision Tree Branches shown in detail in this report are being used to develop three final Decision Tree Branches with emphasis on proven technologies prior to the year 1990 and other sources thereafter. This will allow time to develop data on unproven technologies so they can be more adequately evaluated for second phase development. The three final Decision Tree Branches will be included in the final WMA report as the basis upon which to initiate the Washington Metropolitan Area Future Water Needs Study. They are, however, shown schematically on Figure 6-6. Decision Timing For Initial Projects-WMA (Branches 6-8) are shown in Figure 6-5. Data on the five basic alternatives is presented to assist the reader in understanding the trade-offs among them and how they were used to arrive at the final three alternatives.

The following is a list of projects considered viable for the WMA and used as the basis to select components of regional programs for the Decision Tree Branches according to how well they satisfied the appropriate objectives.

- **Upstream Reservoirs.** Verona Dam and Lake would be located near Staunton, Virginia and could supply 125 to 190 mgd as required for a particular program. The 3,900 acre



\*NOTE: MANY DECISIONS ARE OVERDUE

FIGURE 6-4. DECISION TIMING FOR INITIAL PROJECTS\*\*WMA (BRANCHES 1-5)

#### LEGEND (FIGS. 6-4 AND 6-5)

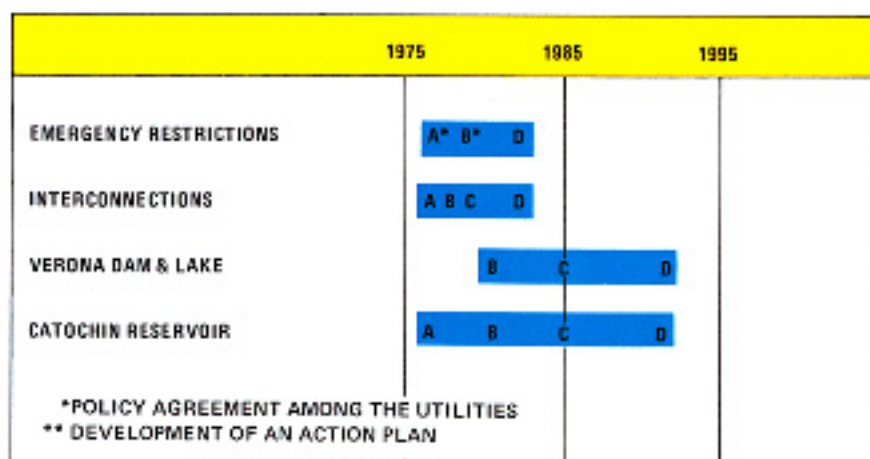
A-LOCAL, STATE, FEDERAL APPROVAL

B-FUNDING FOR ENG. DESIGN

C-FUNDING FOR CONSTRUCTION

\*-PROJECT ON LINE

\*\* NOTE THAT MANY DECISIONS APPEAR LONG OVERDUE



\*POLICY AGREEMENT AMONG THE UTILITIES

\*\* DEVELOPMENT OF AN ACTION PLAN

FIGURE 6-5. DECISION TIMING FOR INITIAL PROJECTS-WMA (BRANCHES 6-8)

project would cost an estimated \$40 million. Sixes Bridge Dam and Lake, near Sixes Bridge, Maryland, could supply 85 to 90 mgd as required at an estimated cost of \$31 million. Both

projects would be operated to increase the average monthly base flow of the Potomac.

- **Estuary Treatment Plant.** Indirect or direct reuse of Potomac estuary water could be accomplished by advanced treatment of water withdrawn from the upper portion of the estuary. Two systems are being considered. The first is a river mix (indirect use) system that would pump between 100 mgd and 200 mgd of treated estuary water 35 river miles upstream of the Washington, D.C. intakes on the Potomac to augment existing stream flows. The second would be a plant mix (direct use) system that could pump between 50 mgd and 100 mgd of treated, estuary water to an existing water supply plant and mix it with plant water.

- **Local Water Impoundments within the WMA.** Local reservoirs on tributaries would be filled by pumping from the Potomac River during higher than normal flows with release to augment the Potomac during low flows. Several sites are under study in Loudoun and Montgomery Counties. These impoundments could supply from 90 to 500 mgd and be used to provide peaking water to meet a portion of the one (1 through 6) day deficits as well as seven (7 through 30) day and monthly deficits.

- **Raw Water Interconnections.** Water would be pumped from the Potomac during high flows to fill existing reservoirs that would, in turn, augment the Potomac during low flow periods. Two existing reservoir systems are under study, the Patuxent and Occoquan. Yield from these interconnections would range from 100 mgd to 265 mgd and could provide water for seven (7 through 30) day deficits.

- **Ground Water.** Two ground water areas were considered, the coastal plain area in Charles and Prince George's Counties in Maryland, which would yield an estimated 100 mgd; and the Hagerstown Valley area of Maryland which could yield an esti-

ated 50 mgd to augment the river during low flows.

- **Indirect Use of Treated Wastewater.** Through the use of advanced wastewater treatment plants (AWT), wastewater could be treated to stream quality standards. One AWT system under consideration in this study would take effluent from the Blue Plains Wastewater Treatment Plant, treat it further, and then discharge it to the Potomac River 35 miles upstream of Washington, D. C. Other AWTs could be located in Loudoun and Montgomery Counties to treat wastewater generated by future growth in these areas. Yields are estimated to range from 35 mgd to 200 mgd. AWT construction is proceeding in the area and can have a beneficial effect on water supply if designed specifically to do so.

- **Land Treatment of Wastewater.** Secondary wastewater treatment plant effluent would be sprayed on land, and through natural biological and physical processes it would be brought to stream quality standards. The water would be recovered through natural run-off into the Potomac. A site under consideration is in Loudoun County. The estimated yield of this project is 25 mgd although 50 mgd would be required for spraying, the difference being lost due to evapotranspiration.

- **Water Demand Reduction.** Three methods of reducing demand are under consideration: 1) Water conservation fixtures such as special water closets, shower heads and spring-return faucets; 2) Water use restrictions to limit or restrict specific uses during emergency situations. These would include such restrictions as a ban on lawn watering, use of ornamental fountains and car wash units that do not have recycle equipment; and 3) Price increases.

## DECISION TIMING

The timing involved for implementation of each project is an important factor which must be considered when projects are selected for inclusion in a plan. The schedules of implementation shown in Figure 6-6 are for the early action projects in each branch of the Decision Tree. They are presented as Federal projects. However, state or local agencies could assume responsibility for some projects, especially the interconnections, local reservoirs, ground water, AWT plants and land treatment. Projects dealing with the regulation and management of water demand, such as pricing, restrictions and plumbing codes, would have to be implemented by local governments.

Interconnections would be the first projects on line in Programs 1A, 1B and 4A and would take a minimum of 10 years to implement. The interconnections would connect the Potomac River as a raw water source with either the W. T. Duckett Reservoir on the Patuxent River operated by the Washington Suburban Sanitary Commission (WSSC) or the Occoquan Reservoir operated by the Fairfax County Water Authority (FCWA). Initial indications as to the effects of mixing Potomac River water with the water in either existing reservoir are favorable, but detailed impacts of the interconnections will have to be carefully studied before construction. Rights of way will have to be obtained for the pipeline routes and approval will be needed by Federal, State and County agencies and the WSSC. The initial decisions should already have been made if either or both of these projects were to have been constructed in time to acceptably lower the risk of seven (7 through 30) day shortages.

AWT plants, the first project to come on-line in Programs 2 and 3, would take a minimum of 9 years to implement. The design, authorization and appropriation time might have to be extended due to the present hesitancy

to advocate treated wastewater as a source of water supply. AWT plants would need the approval of Federal, State and County agencies. It is too late to make decisions to bring these projects on line in time to acceptably lower the risk of seven (7 through 30) day shortages.

The Catoctin High Flow Skimming Impoundment in Virginia is the first project to come on-line in Program 4-B and would take a minimum of 8 years to implement. Due to the present local opposition in Loudoun County to the destruction of historic land sites and diminishment of scenic, cultural and esthetic value of the area caused by this project, State and local approval might take longer than the estimated two years. This high flow skimming impoundment would need the approval of Federal, State and County agencies. Land, easements and rights of way would have to be obtained. It is too late to make decisions to bring this project on line in time to acceptably lower the risk of seven (7 through 30) day shortages.

Goose Creek High Flow Skimming Impoundment is the only project needed after Bloomington to meet monthly water demands until 2020 in Program 4C. Eight years is needed as a minimum to implement this project. Due to the large number of acres inundated and its location in Loudoun County, State and local approval may take longer than the estimated two years. Goose Creek High Flow Skimming Impoundment would require Federal, State and County agencies' approval. Land, easements and rights of way would have to be obtained. It is too late to make decisions to bring this project on line in time to acceptably lower the risk of seven (7 through 30) day shortages.

The Little Monocacy High Flow Skimming Impoundment is the first project to come on line in Program 5A and would take a minimum of 8 years to

implement. The Little Monocacy is located in an increasingly urbanized area and would therefore require careful land use planning before State and local approval could be obtained. This high flow skimming impoundment would require Federal, State and County agency approval. Land, easements and rights of way would have to be obtained. It is too late to bring this project on line to acceptably lower the risk of seven (7 through 30) day shortages.

Verona Dam and Lake has already received State and Federal approval through the design stage. Verona Dam and Lake would require additional Federal and State agencies' and County approval for construction. Land, easements and rights of way would have to be obtained. Verona Dam and Lake cannot be operational in time to acceptably lower the risk of seven (7 through 30) day shortages. In addition, the 27 days it takes for water to travel from the dam to the WMA makes it inefficient to use as a seven day source. Since the time for decisions or actions to implement the early projects on branches 1 through 5 has passed, Figure 6-5 has been developed for branches 6 through 8 reflecting timing of decisions or actions needed to reduce the risk of seven day shortage. Branches 6 and 8 will require the development of a restriction policy severe enough to reduce demands to the winter level.

#### PLANNING ASSUMPTIONS

The following assumptions were made to formulate the alternative programs shown on the decision tree:

1. Water supplies will be provided to meet projected average monthly demands. Demand projections have been reduced to reflect use reductions through water saving fixtures and appliances of 1 mgd per year after 1975, for a total of 45 mgd by 2020. WMA demand was then disaggregated into Potomac and non-Potomac de-

mands. The programs compare Potomac supplies with Potomac demands.

2. Short term peak deficits between 7 and 30 days duration are alleviated with peaking projects which supply large quantities of water for short periods or through emergency water restrictions that reduce the short term peak demand. Application of restrictions could reduce monthly demand to the level approximated by winter demands, when lawn watering, filling of swimming pools and similar non-essential activities are at a minimum.
3. In all programs peak deficits of less than 7-days duration may be alleviated using demand reduction through emergency restrictions, local storage provided by water utilities, by reducing the 100 mgd minimum flow into the estuary, or by using the emergency intake.
4. Yield is based on the monthly minimum safe yield of the Potomac River at Point of Rocks less 100 mgd minimum flow to the estuary.
5. Bloomington Dam and Lake, now under construction on the North Branch of the Potomac River, will be operational by 1979.

#### COST AND CASH FLOW

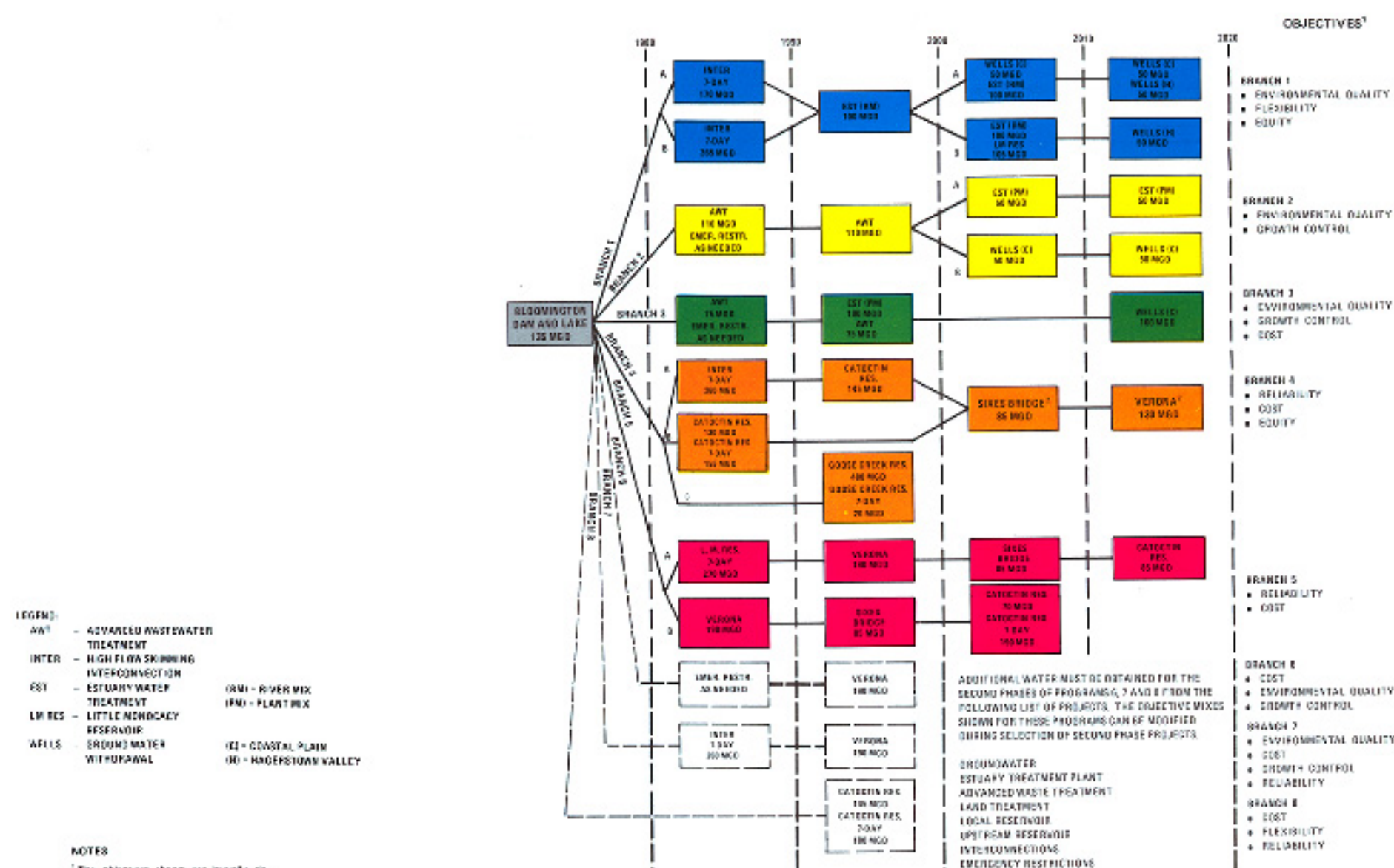
Local expenditure and cost data have been developed and are displayed for Decision Tree Branches 1 through 5. These data demonstrate the financial sensitivity of program and user costs to local and extra local funding source assumptions. Comparison of estimated annual local expenditures through 2020 for both amortized capital construction costs and operation, maintenance and repair costs shows that it is less expensive to use extra local

tenance and repair costs shows that it is less expensive to use extra local funding during the 50 year period (1970-2020) of analysis. This analysis was based upon the assumption that the 1958 Water Supply Act may be applied to obtain extra local funding. It includes a lower interest rate and a longer payback period, resulting in

small annual payments, as well as an initial period of up to ten years until a project comes on line during which no debt service payments are made and no interest is accrued. However, since in all cases local cash outlays extend beyond 2020, total program cash outlays are slightly greater, less than 1%, with extra local funding. Estimated

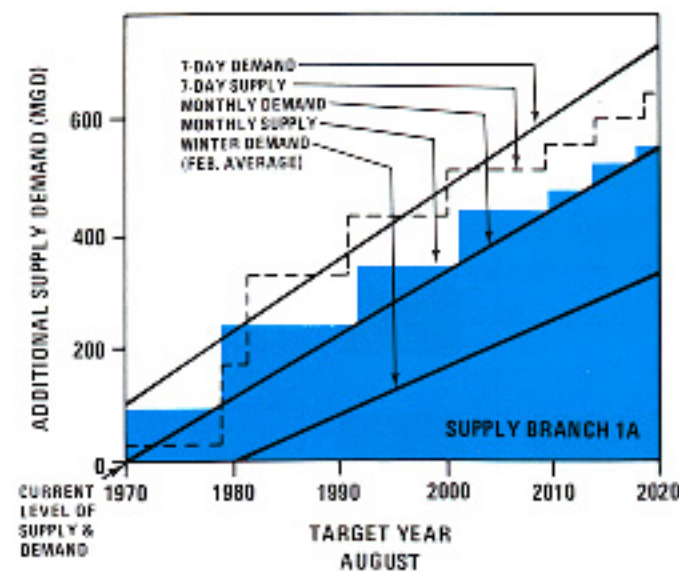
cost per mgd of safe yield for 1980, 2000 and 2020 is higher for local funding because it has been calculated on the basis of a 10% reserve on debt service which is typically required by investment bankers on municipally funded projects.

FIGURE 6-6. DECISION TREE—WMA PROJECTS

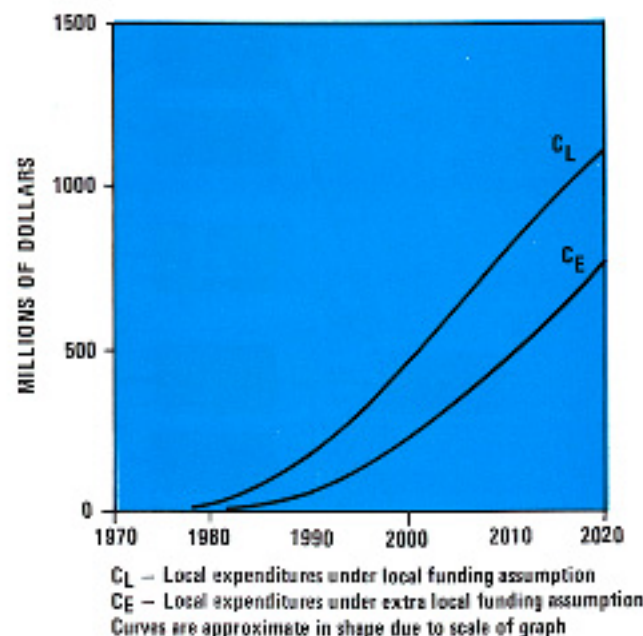


	1992				1993				1994				1995				1996				1997				1998			
	MONTH		1 DAY		MONTH		1 DAY		MONTH		1 DAY		MONTH		1 DAY		MONTH		1 DAY		MONTH		1 DAY		MONTH		1 DAY	
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
BRANCH	NO. SUPPLY	LOCAL CAP	LOCAL CAP	LOCAL CAP	NO. SUPPLY	LOCAL CAP	LOCAL CAP	LOCAL CAP	NO. SUPPLY	LOCAL CAP	LOCAL CAP	LOCAL CAP	NO. SUPPLY	LOCAL CAP	LOCAL CAP	LOCAL CAP	NO. SUPPLY	LOCAL CAP	LOCAL CAP	LOCAL CAP	NO. SUPPLY	LOCAL CAP	LOCAL CAP	LOCAL CAP	NO. SUPPLY	LOCAL CAP	LOCAL CAP	LOCAL CAP
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1A	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1B	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1C	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1D	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1E	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1F	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1G	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1H	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1I	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1J	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1K	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1L	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1M	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1N	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1O	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1P	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1Q	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1R	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1S	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1T	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1U	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1V	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1W	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1X	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1Y	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1Z	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

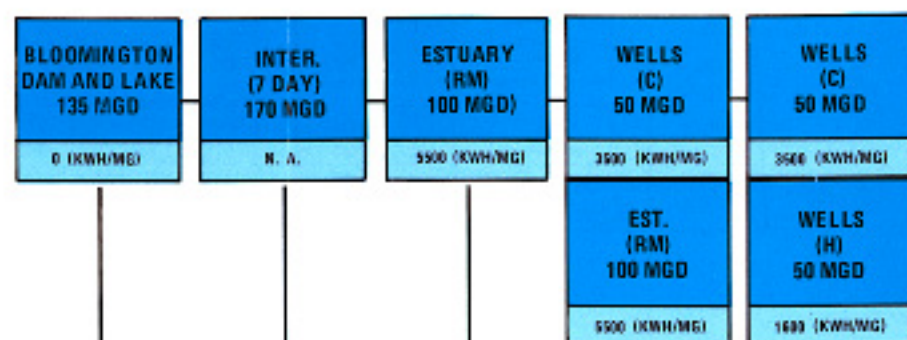
# ADDITIONAL SUPPLY DEMAND VS. TIME BRANCH 1A



# CUMULATIVE EXPENDITURES FOR BRANCH 1A



# DECISION TREE - BRANCH 1A (AUGUST)



YEAR	1970		1980		1990		2000		2010		2020	
	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY
ADDITIONAL DEMAND (MGD)	-	-	135	155	245	280	355	410	465	535	575	665
ADDITIONAL SUPPLY (MGD)	120*	30*	255	105	255	335	355	435	505	585	605	685
ENERGY REQUIREMENTS (KWH/MG)	-	-	0		0		1500		2500		2500	

\* SURPLUS POTOMAC RIVER FLOW

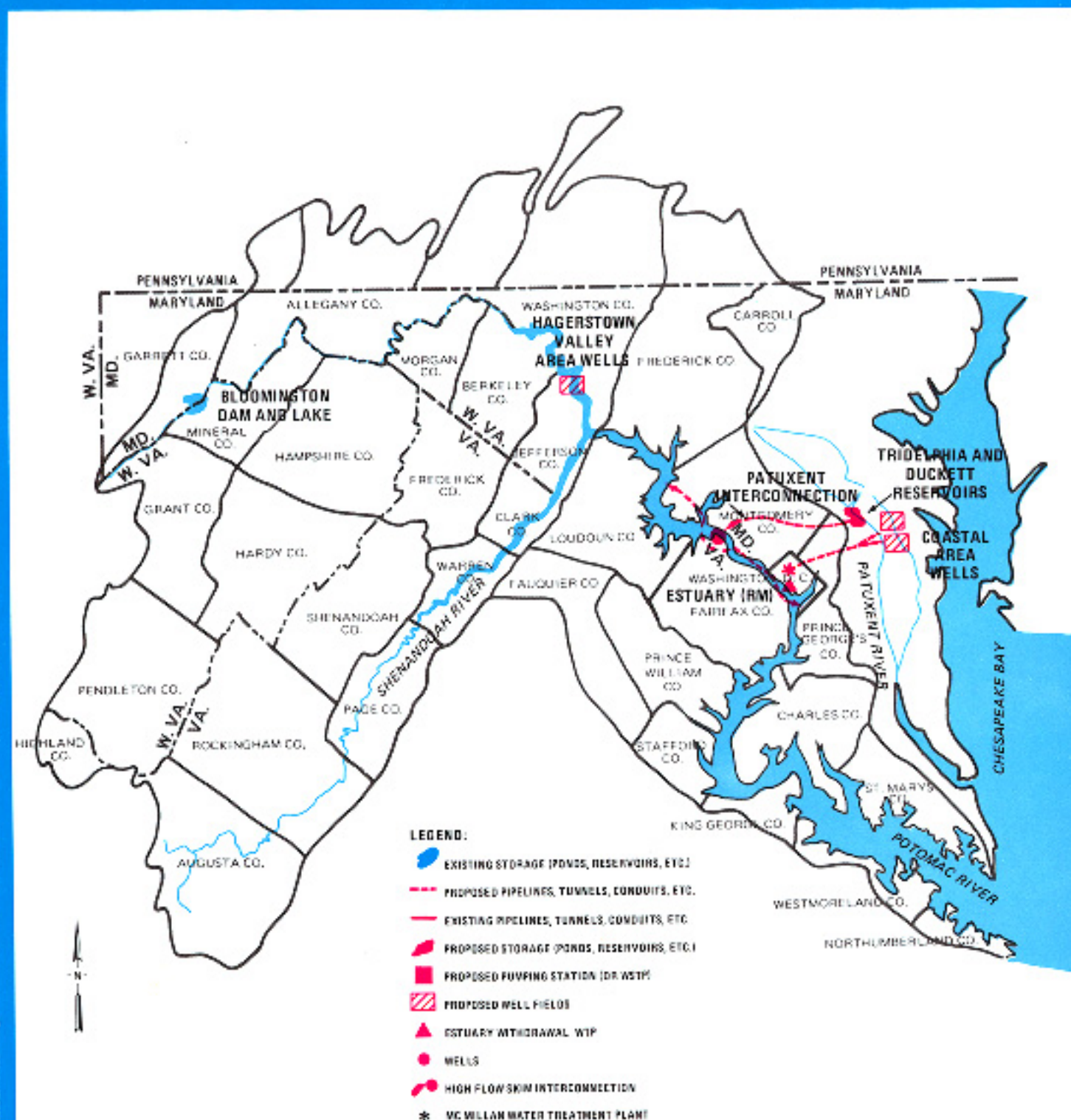
\*\* AVERAGE

# BRANCH 1A

• ENVIRONMENTAL QUALITY

• EQUITY

• FLEXIBILITY



**BRANCH NUMBER ONE** — A program designed to satisfy the objectives of environmental quality, flexibility, and equity, as well as water supply.

Branch 1 is formulated to minimize health risk by delaying use of the estuary until more questions can be answered by the pilot estuarine treatment plant. In addition, it complements satisfaction of environmental quality by minimizing large scale, land intensive reservoir construction; flexibility in terms of multi purpose function and ease of building increments; and equity in terms of the most equal distribution of non-monetary costs and benefits.

#### Program Descriptions — 1A and 1B

1980 — With Bloomington Dam and Lake operating by 1980, adequate supplies to meet monthly demands are available. However, seven day deficits could occur but may be met by restrictions as needed.

1990 — An interconnection routed through Montgomery County

between the Potomac River and existing Patuxent Reservoirs is needed to alleviate the seven day demands through 2020. In Program 1A the interconnection would supply an additional 170 mgd and in Program 1B an additional 265 mgd.

2000 — To meet monthly demands for both programs, the first stage of the River Mix Estuary Treatment Plant located in Washington, D.C. would be brought on line to supply an additional 100 mgd.

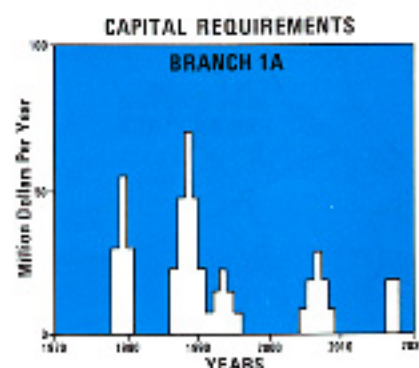
2010 — In both Programs 1A and 1B, stage two of the Estuary Treatment Plant would supply an additional 100 mgd. In 1A 50 mgd would also be necessary from wells constructed on the Maryland coastal plain. Instead of wells, a high flow skimming dam and lake project, on the Little Monocacy in Montgomery County, supplying 105 mgd, would be constructed in Program 1B.

2020 — Wells constructed in the Hagerstown Valley area of Maryland would provide 50 mgd for demands in both 1A and 1B. However, an additional 50 mgd from wells in the Maryland coastal plain are needed in Program 1A.

#### Program Rationale

Interconnections, a river mix estuary treatment plant and two wellfield areas, one in the coastal plain and the other in the Hagerstown Valley, are the projects selected for Program 1A.

The seven day interconnections projects best meet the objectives of high



#### PROJECT DATA FOR BRANCH 1A\*\*

PROJECT	ULTIMATE		CAPITAL COST* \$ MILLIONS	ANNUAL* OM&R \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$MILLIONS)					
						THROUGH 1980		THROUGH 2000		THROUGH 2020	
	MONTH	7-DAY				LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
	SAFE YD. MGD	SAFE YD. MGD									
BLOOMINGTON	135	135	—	—	0	—	—	—	—	—	—
INTER- CONNECTION	0	170	120.71	.85	23,200	25.4	0	213.6	138.6	334.1	277.2
ESTUARY	200	200	280.58	2.29	37,400	0	0	264.1	129.8	703.3	444.6
WELLS (C)	100	100	86.82	.81	14,800	0	0	0	0	95.2	56.2
WELLS (H)	50	50	37.67	.42	3,300	0	0	0	0	14.5	6.9
SURPLUS (1970)	120	30									
TOTAL	605	685	525.78	9.14	78,700	25.4	0	477.7	268.4	1147.1	783.9

\*AT COMPLETION

\*\*ALL FIGURES IN 1974 DOLLARS

reliability, environmental quality and social and economic equity. They offer proven ability to meet water quality standards as well as a reliable source of water. Environmentally, they have high energy requirements, require little land and have minimal effect on aquatic and animal life, natural habitat, vegetation, etc. In regard to equity, costs and benefits are well distributed in the region. Construction would only occur close to the WMA. Although interconnections offer flexibility in the quantity of water which can be obtained, it is desirable to build the pipeline to its ultimate capacity because of the inefficiency involved in building a series of smaller pipelines as needed.

The river mix estuary treatment plant and wellfields provide monthly needs and complete the projects for this program. Although trade offs must be made among the objectives, on the whole these projects assist to satisfy most objectives. The estuary and wellfields rank high in environmental quality with the exception of the high

energy requirements for operating the estuary treatment plant and for pumping estuarine water up to Dickerson, Maryland. The estuary plant could provide a large volume of water but would create water quality questions due to the uncertainty of operating an estuary plant that will always meet river water standards. Wells on the other hand, may provide high quality water, but quantities remain a question due to as yet unproven yields.

Flexibility to increase output is high in the case of wells and moderate for the estuary plant.

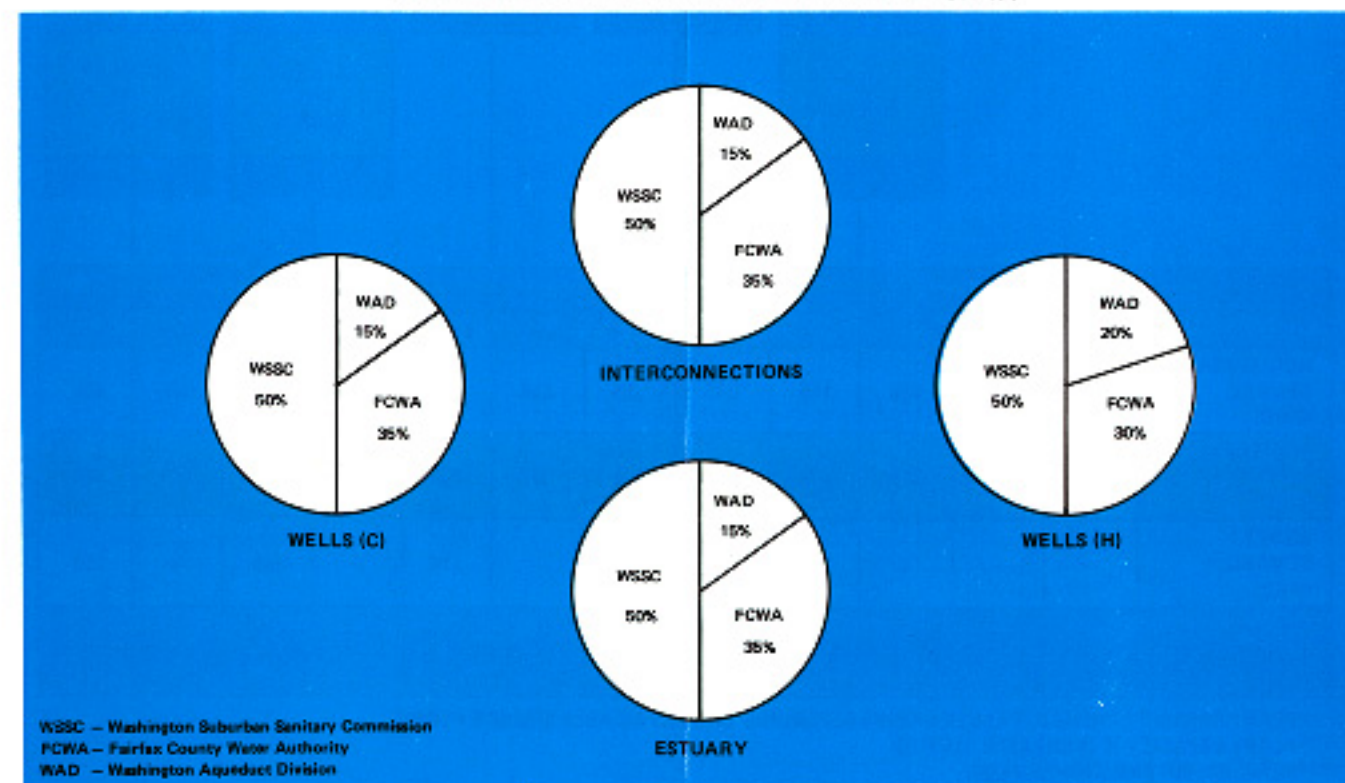
Social and economic equity, is served well by the estuary but less so by the wellfields. The river mix estuary uses local sources but the wellfields are located some distance from those who benefit most.

With the exception of the interconnections, the projects in Program 1A may be considered as examples of new or unproven technology. The potential for wells has yet to be established and uncertainty remains as

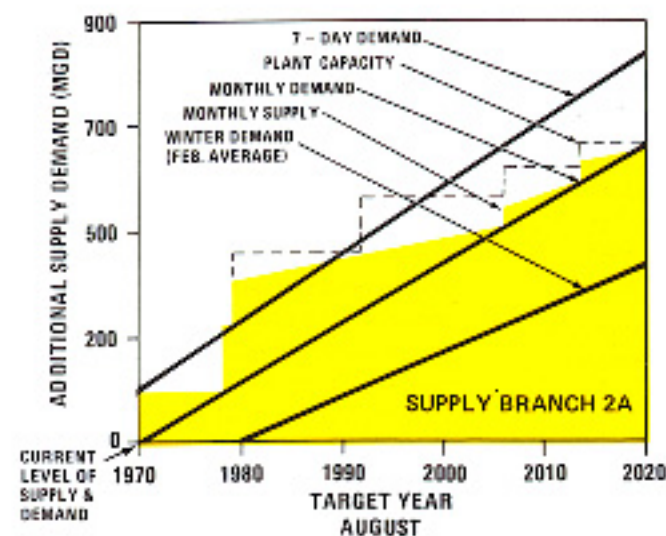
to the quality of the treated estuary water in terms of sustained yield, reliability and health risks. These unproven technologies require pilot efforts to resolve the uncertainties related to their use.

Program 1B is in most respects identical to Program 1A, except larger interconnections were used to provide greater seven day peaking capability and a Potomac high flow skimming project on the Little Monocacy instead of the Coastal Plain Wells. Program 1B generally serves the objectives of this program as well as 1A with the size of the interconnection making little difference. The Little Monocacy impoundment, on the other hand, brings its own characteristics to bear on the objectives. The reservoir could provide not only water supply but also some limited recreational benefits. It would provide a reliable, source of water of known quality. Equity questions could arise at the local level regarding land acquisition in Montgomery County to supply the metropolitan area.

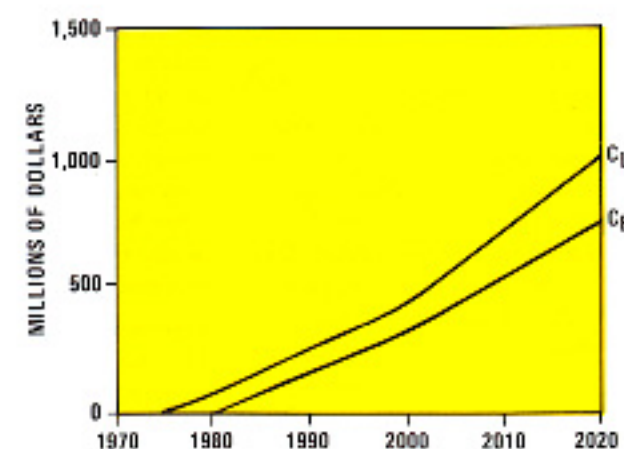
#### DISTRIBUTION OF EXPENDITURES FOR BRANCH 1A



## ADDITIONAL SUPPLY DEMAND VS. TIME BRANCH 2A

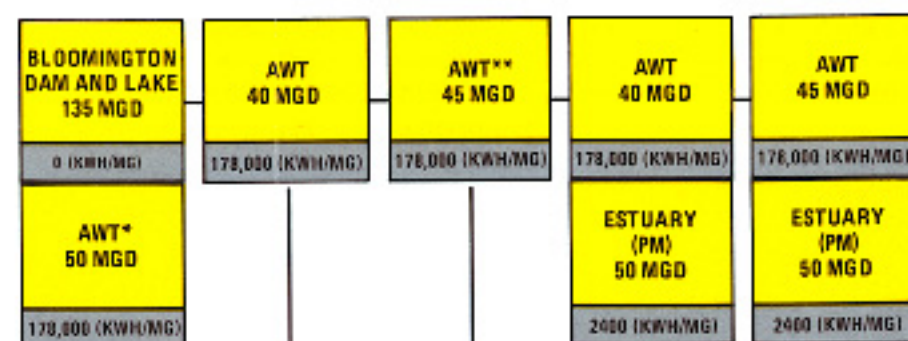


## CUMULATIVE EXPENDITURES FOR BRANCH 2A



CL - Local expenditures under local funding assumption  
CE - Local expenditures under extra local funding assumption  
Curves are approximate in shape due to scale of graph

## DECISION TREE - BRANCH 2A (AUGUST)



YEAR	1970		1980		1990		2000		2010		2020	
	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY
ADDITIONAL DEMAND (MGD)	—	—	135	155	245	280	355	410	465	535	575	665
ADDITIONAL SUPPLY (MGD)	120 ***	30 ***	305	215	345	255	390	300	480	390	575	485
UNMET + DEMAND (MGD)	—	—	—	—	—	25	—	110	—	145	—	180
ENERGY REQUIREMENTS <sup>++</sup> KWH/MG	—	—	29,100		46,400		61,500		65,000		68,400	

\*PLANT CAPACITY 110 MGD, VALUES Varies DEPENDING UPON AVAILABLE SEWAGE FLOWS

\*\*PLANT CAPACITY IS INCREASED 110 MGD

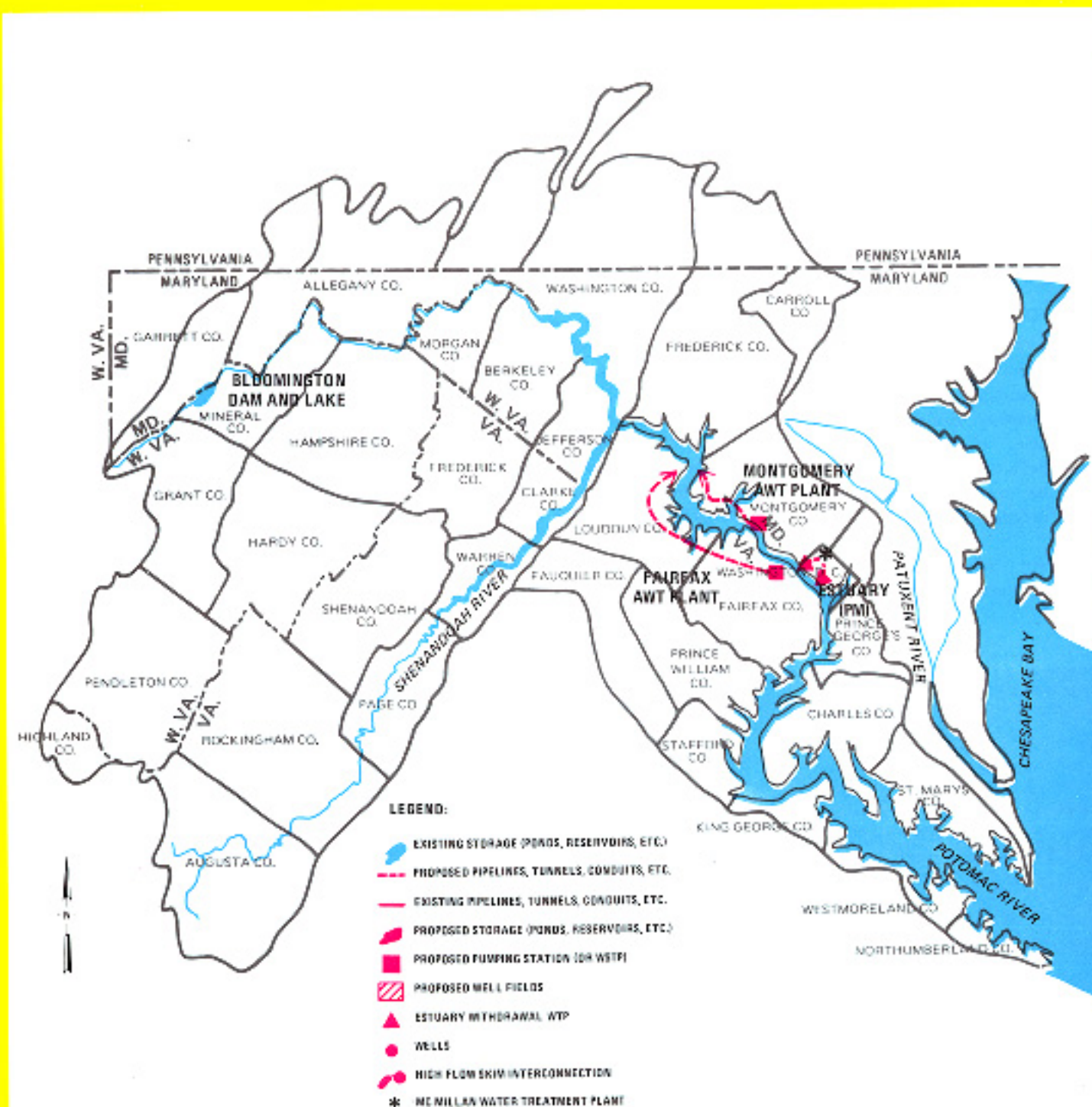
\*\*\*SURPLUS POTOMAC RIVER FLOW

-MUST BE MET THROUGH DEMAND RESTRICTIONS

++ AVERAGE

## BRANCH 2A

- ENVIRONMENTAL QUALITY
- GROWTH CONTROL



**BRANCH NUMBER TWO** — A program designed to satisfy the objectives of environmental quality and growth control, as well as water supply.

Branch 2 was formulated to minimize adverse impact to the environment and complement a low growth policy for the WMA. The impact to the environment was measured as number of acres of land affected, the extent of impact on stream water quality, consumption of energy, and the degree of alteration of vegetation, aquatic and natural habitats. The effect on growth was measured by the amount of land temporarily or permanently taken out of development in the WMA and the ease with which yields of water supply could be increased in small steps to service small increases in population.

#### Program Descriptions — 2A and 2B

1980 — With Bloomington operating by 1980 adequate supplies to meet monthly water supply demands are available. Waste treatment plants would begin to be built in stages in Fairfax

and Montgomery Counties with a combined capacity to treat 110 mgd of wastewater generated in the region to stream quality standards. They would discharge into the Potomac River 35 river miles upstream of Washington, D.C.

1990 — Seven day deficits will exist from this time frame on and will be met through emergency restriction procedures. These would be implemented to reduce peak demands up to 170 mgd rather than provide additional seven day supply.

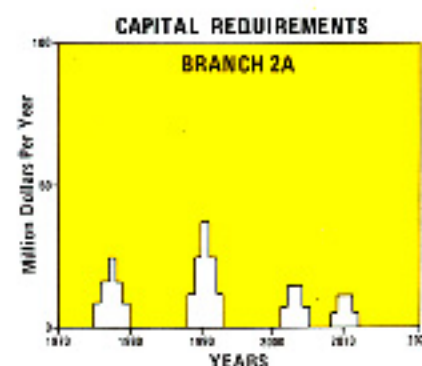
2000 — With an expansion of the AWT plants in Montgomery and Fairfax Counties, an additional 110 mgd would be added to the area's supply capacity.

2010 — A plant mix estuary treatment plant, supplying 50 mgd is constructed in Washington, D.C. by 2010. In program 2B an additional 50 mgd is available from wells in the Coastal Plain.

2020 — Program 2A supplies an additional 50 mgd by expanding the plant mix estuary treatment plant. Expansion of the Coastal Plain Wells supplies 50 mgd in Program 2B.

#### Program Rationale

Program 2A consists of emergency restrictions, AWT plants, and a plant mix estuary treatment plant. In this program there is no physical project specifically included for handling the seven day peaking problem. Instead this problem would be handled by emergency water use restrictions.



This program complements environmental quality and growth control objectives quite well. The emergency restrictions would have only a limited environmental impact centering in the upper estuary. Since a peaking facility to meet seven day peaking problems is lacking, restrictions may tend to retard growth if local ordinances are enacted. Environmentally, using existing AWT plants for water supply has a number of advantages. They require little additional land, enhance instream water quality by augmenting low flows and cause minimal disruption of natural habitat, animals, vegetation and aquatic life. Their major detriment, however, is their comparatively high energy requirements for plant processes and for pumping especially since the AWT plants would be operating year round. However, AWT plants are flexible and can be incremented as

required by the amount of growth in a county also complementing low growth policies.

A plant mix estuary treatment plant would have a similar effect on growth as that of the AWT plants. Environmentally, it requires less land but has a potentially adverse effect on the environment of the upper estuary, when estuarine withdrawals are coupled with a low flow regime.

Program 2B is similar to Program 2A except the plant mix estuary treatment plant is replaced by coastal plain wells. This project also complements environmental quality and low growth policies quite well. The wells require a moderate amount of land, a moderate amount of energy and have very little impact on ecological systems, aquatic

and terrestrial. Wells are fairly easy to increment as needed when growth requires. Recharge areas and areas immediately surrounding the wells need to be protected and offer the opportunity for local land use ordinances to do so for both protection and control of growth. Program 2A is primarily one of wastewater reuse, relying heavily on AWT plants and estuarine withdrawals. In both programs the technologies are relatively unproven except for wells. Before this program can be successfully launched the performance of these projects will have to be proven.

#### PROJECT DATA FOR BRANCH 2A\*\*

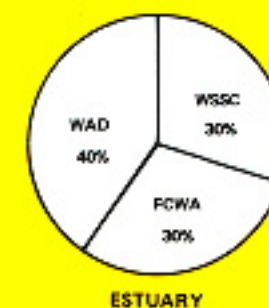
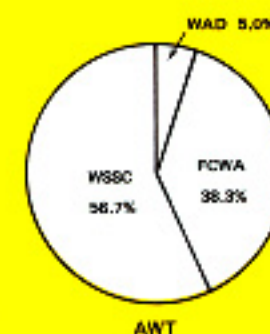
PROJECT	ULTIMATE		CAPITAL COST* \$ MILLIONS	ANNUAL* OM&R \$ MILLIONS	CONNECTED LOAD (KW)	LOCAL EXPENDITURES (\$ MILLIONS)					
						THROUGH 1980		THROUGH 2000		THROUGH 2020	
	MONTH	7-DAY				LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING		
	SAFE YD. MGD	SAFE YD. MGD									
BLOOMINGTON	135	135	—	—	0	—	—	—	—	—	—
AWT <sup>+</sup>	220	220	189.66	11.01	44,000	37.6	9.3	401.9	284.0	887.9	692.0
ESTUARY	180	180	82.02	.83	9,700	0	0	0	0	187.9	63.1
SURPLUS	120	30									
TOTAL	575	485	271.58	11.84	53,700	37.6	9.3	401.9	284.0	995.8	755.1

\*AT COMPLETION

\*\*ALL FIGURES IN 1974 DOLLARS

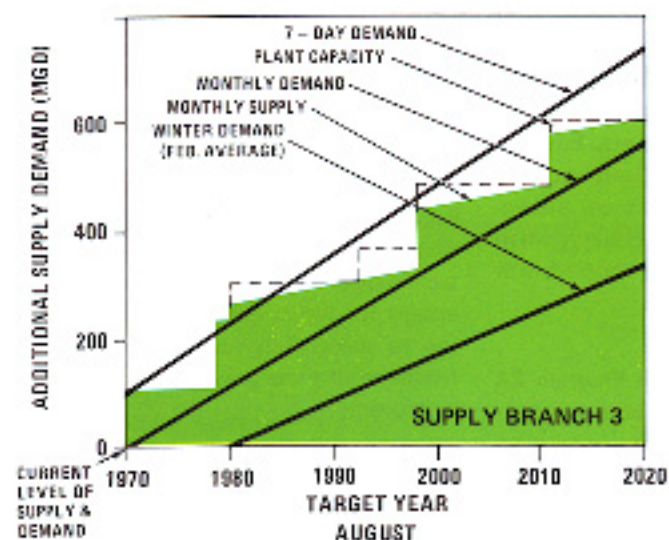
\*COST ANALYSIS BASED ONLY ON WATER SUPPLY

#### DISTRIBUTION OF EXPENDITURES FOR BRANCH 2A

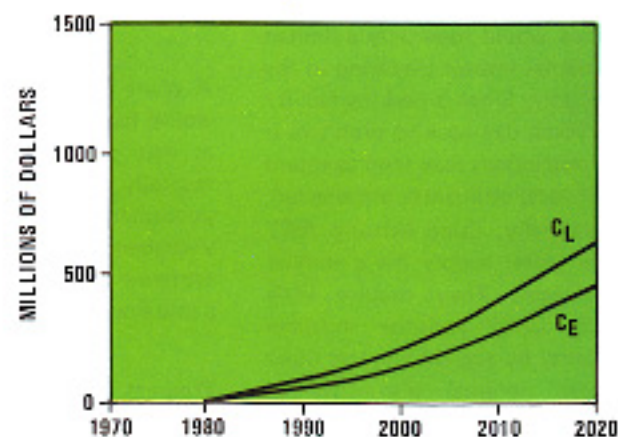


WSSC — Washington Suburban Sanitary Commission  
FCWA — Fairfax County Water Authority  
WAD — Washington Aqueduct Division

# ADDITIONAL SUPPLY DEMAND VS. TIME BRANCH 3



## CUMULATIVE EXPENDITURES FOR BRANCH 3



CL - Local expenditures under local funding assumption  
CE - Local expenditures under extra local funding assumption  
Curves are approximate in shape due to scale of graph

## DECISION TREE - BRANCH 3 (AUGUST)



YEAR	1970		1980		1990		2000		2010		2020	
	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY
ADDITIONAL DEMAND (MGD)	-	-	135	165	245	280	355	410	465	535	575	665
ADDITIONAL SUPPLY (MGD)	120***	30***	285	195	315	225	445	355	475	385	605	515
UNMET & DEMAND (MGD)	-	-	-	-	-	55	-	55	-	150	-	150
ENERGY REQUIREMENTS ++ (KWH/MG)	-	-	12,300		22,300		24,300		30,100		30,100	

\* PLANT CAPACITY 75 MGD; VALUE VARIES DEPENDING UPON AVAILABLE SEWAGE FLOWS

\*\* PLANT CAPACITY IS INCREASED 75 MGD

\*\*\* SURPLUS POTOMAC RIVER FLOW

+ MUST BE MET THROUGH DEMAND RESTRICTIONS

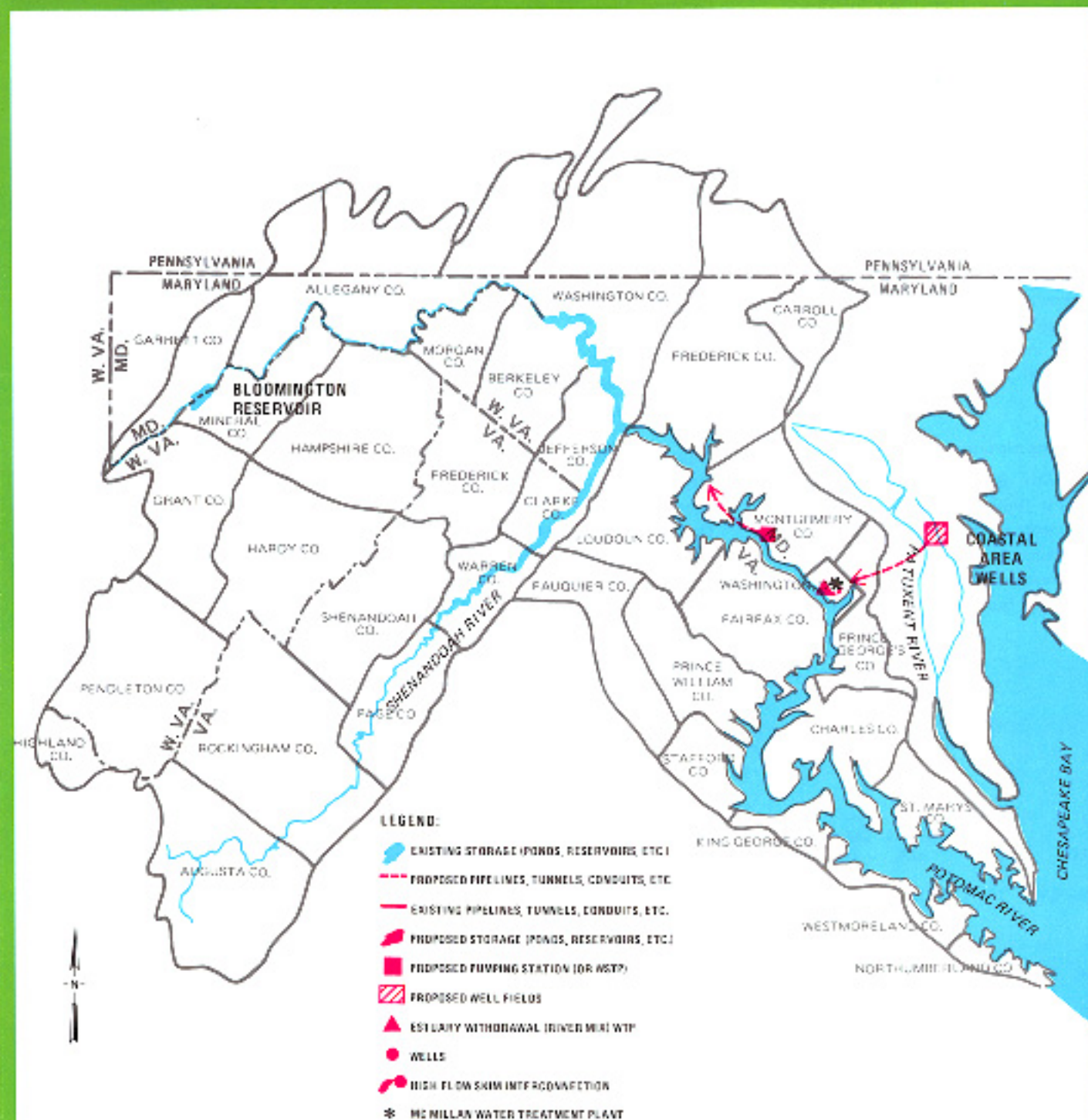
++ AVERAGE

## BRANCH 3

• ENVIRONMENTAL QUALITY

• GROWTH CONTROL

• COST



**BRANCH NUMBER THREE** — A program designed to satisfy the objectives of cost, environmental quality, and growth control, as well as water supply. Branch 3 complements environmental quality and growth control objectives in as cost efficient a manner as possible.

#### Program Description — 3

1980 — With Bloomington operating by 1980, adequate supplies to meet monthly water supply demands are available. Wastewater at the Montgomery County Advanced Waste Treatment Plant will be treated to stream quality standards and discharged into the Potomac upstream of the water supply intakes. First stage plant capacity would be 75 mgd.

1990 — Seven day deficits will exist from this time frame on and will be met through emergency restriction procedures. These would be implemented to reduce peak demands up to 145 mgd rather than provide additional seven day supply.

2000 — Expansion of the Montgomery County AWT Plant increases the supply capacity another 75 mgd, for a total of 150 mgd. A plant mix estuary treatment plant, constructed in Washington, D.C. would supply 100 mgd.

2010 — No additional supply necessary to meet projected monthly demands.

2020 — To meet increasing demands, wells in the Coastal Plain

would add 100 mgd to the WMA supply.

#### Program Rationale

Emergency restrictions, AWT plants, a plant mix estuary treatment plant and coastal plain groundwater are the projects in Program 3. In projects and objectives this program is in many ways similar to a composite of Program 2A and B. The only new ob-

jective is low cost. As in Program 2, no facilities would be constructed specifically for meeting seven day peak demands. Instead, emergency water use restrictions of up to 145 mgd would be required.

As in Program 2, restrictions, AWT plants, estuary treatment plants, and wells complement the environmental quality objective fairly well. Small to moderate amounts of land are used. Operation of the projects during low flow periods could add to adverse conditions existing within the upper estuary. Again, the major environmental drawback is the high energy requirements of the AWT plants and estuary treatment plants.

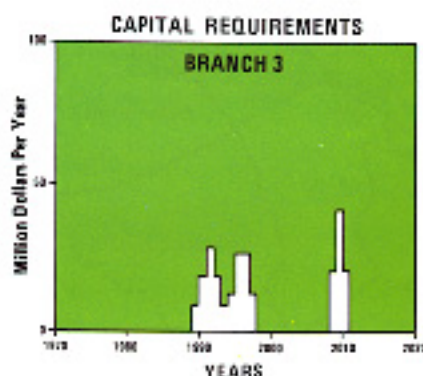
This program, unlike Program 2, does not contribute as much to low growth. Since low cost is also a factor, trade-offs are made between low growth and

low cost. The effect being that to lower cost, the estuary plant and coastal wells are built to full capacity in one stage instead of in growth related increments. Restrictions and AWT plants are not affected by cost considerations and still complement low growth policies.

The projects have moderate capital and operating costs for water supply with the exception of the estuary plant which has relatively high operating cost. The program could also be considered equitable since it relies largely on local sources, however, the equitability of a restriction program must be carefully considered by local interests.

This program brings into circulation and recirculation a large amount of water from the new technologies. It also demands commitment to a course

of action that may not be completely successful because of the unproven technologies involved.



PROJECT DATA FOR BRANCH 3\*\*

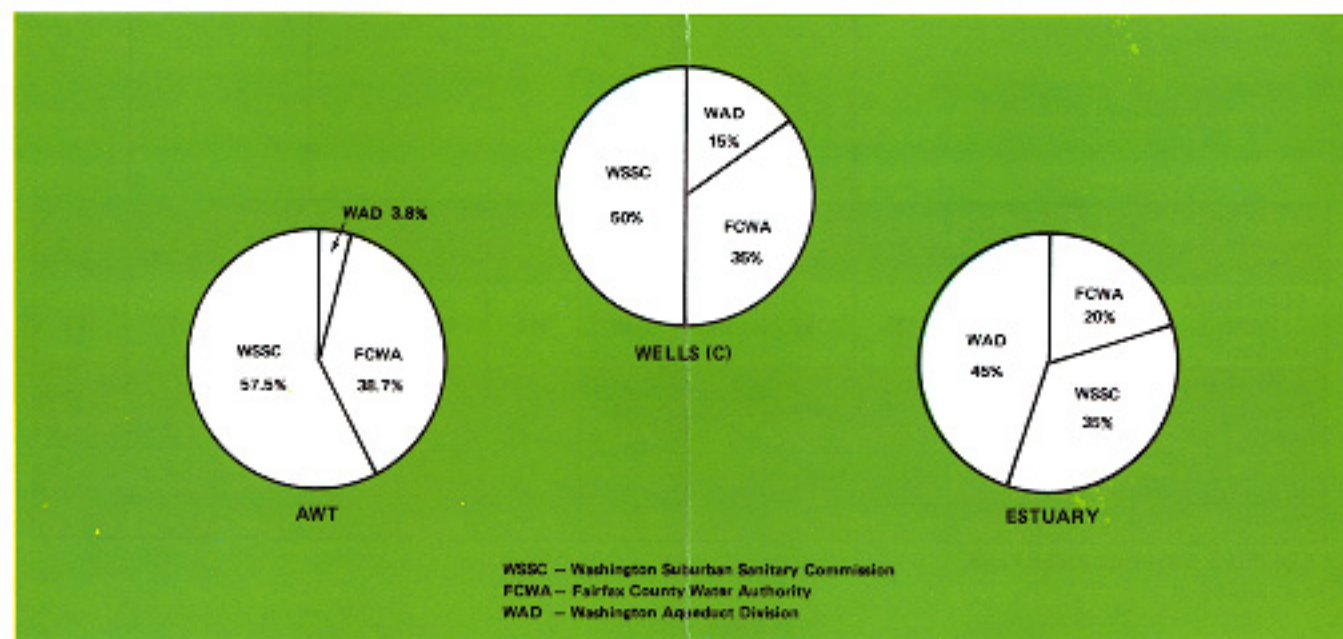
PROJECT	ULTIMATE		CAPITAL COST* \$ MILLIONS	ANNUAL* OM&R \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$ MILLIONS)					
	MONTH SAFE YD. MGD	7-DAY SAFE YD. MGD				THROUGH 1980		THROUGH 2000		THROUGH 2020	
						LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
BLOOMINGTON	135	135	—	—	0	—	—	—	—	—	—
AWT <sup>†</sup>	150	150	88.13	5.25	30,000	2.6	2.6	147.8	104.2	376.5	236.3
ESTUARY	100	100	83.53	.73	9,700	0	0	38.5	13.3	157.5	101.9
WELLS (C)	100	100	66.52	.55	14,800	0	0	0	0	88.4	52.4
SURPLUS	120	30									
TOTAL	805	515	258.18	6.53	54,500	2.6	2.6	186.3	117.5	622.5	451.1

\*AT COMPLETION

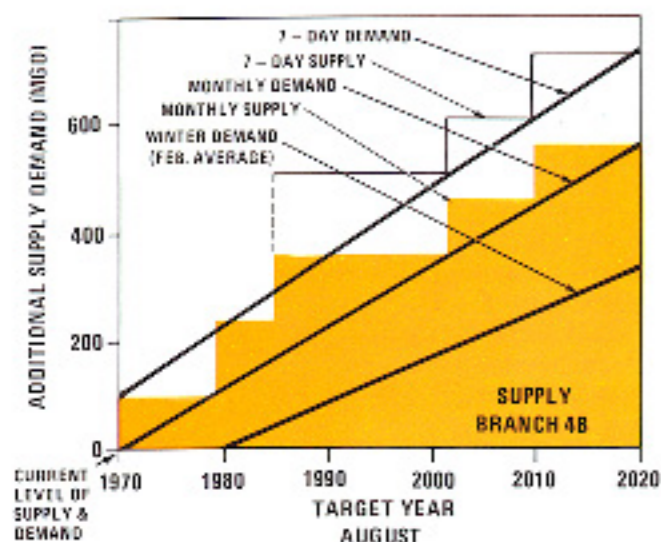
\*\*ALL FIGURES ARE IN 1974 DOLLARS

\*COST ANALYSIS BASED ONLY ON WATER SUPPLY COSTS

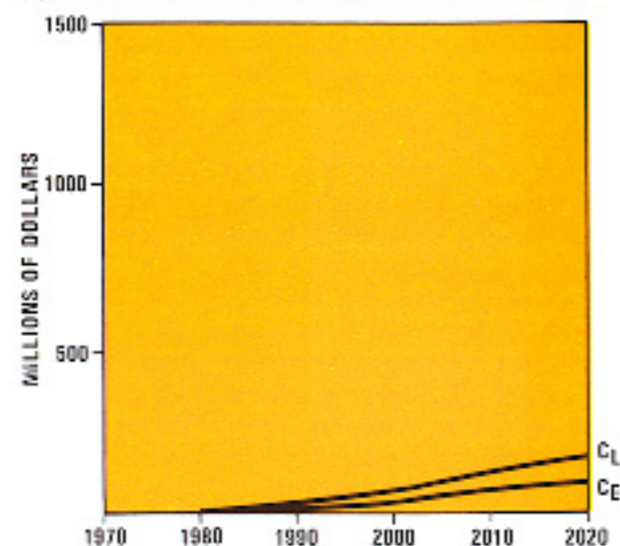
DISTRIBUTION OF EXPENDITURES FOR BRANCH 3



# ADDITIONAL SUPPLY DEMAND VS. TIME BRANCH 4B



## CUMULATIVE EXPENDITURES FOR BRANCH 4B



$C_L$  - Local expenditures under local funding assumption  
 $C_E$  - Local expenditures under extra local funding assumption  
 Curves are approximate in shape due to scale of graph

## DECISION TREE - BRANCH 4B (AUGUST)



YEAR	1970		1980		1990		2000		2010		2020	
	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY
ADDITIONAL DEMAND (MGD)	-	-	135	155	245	280	355	405	465	535	575	665
ADDITIONAL SUPPLY (MGD)	120*	30*	255	165	385	450	385	450	470	535	600	665
ENERGY REQUIREMENTS ** KWH/MG	-	-	0		20		20		10		10	

\* SURPLUS POTOMAC RIVER FLOW

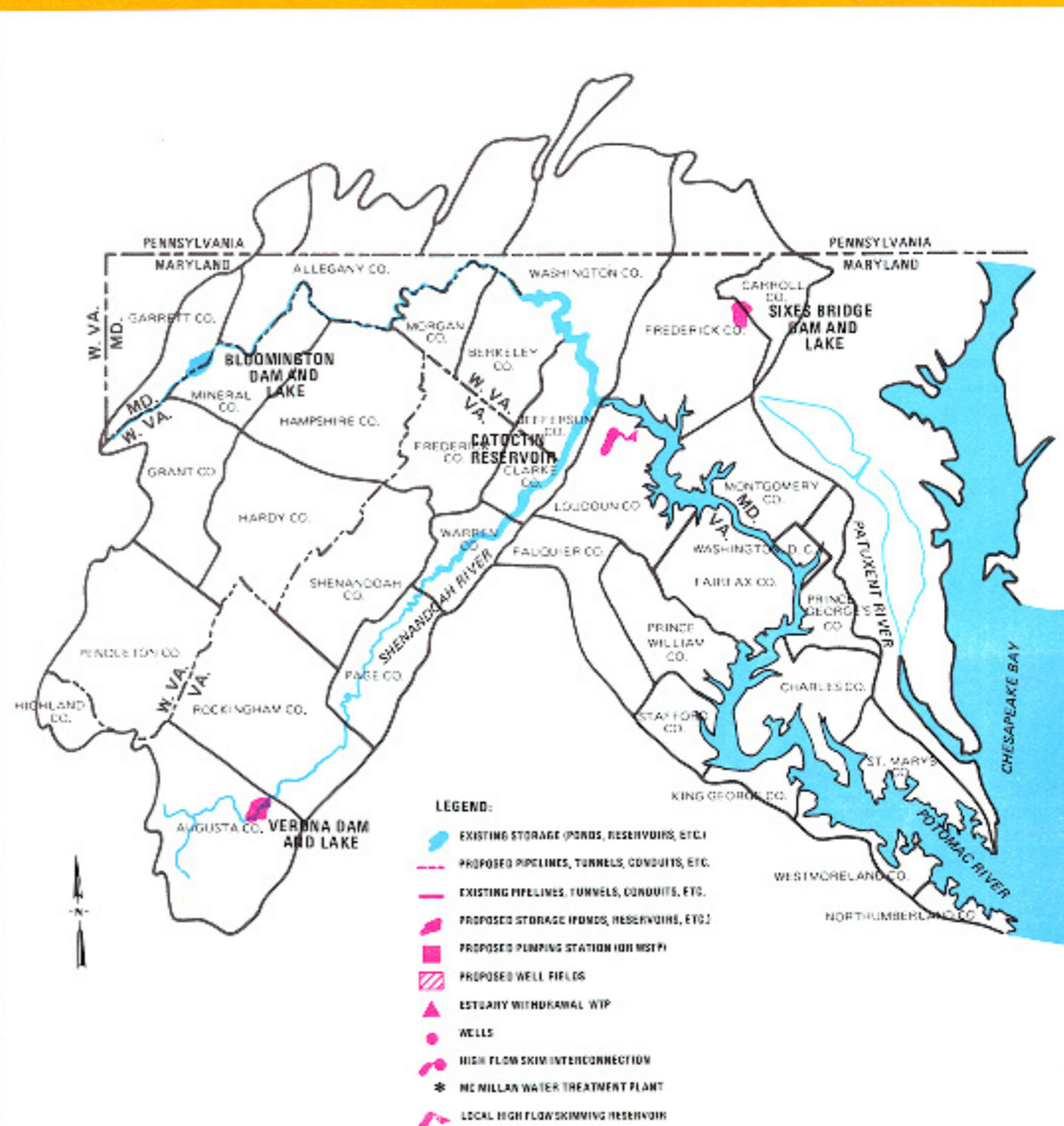
\*\* AVERAGE

## BRANCH 4B

• RELIABILITY

• EQUITY

• COST



**BRANCH NUMBER FOUR** — A program designed to satisfy the objectives of reliability, cost, and equity, as well as water supply.

Branch 4A represents a mix of objectives for individuals concerned primarily with public health, the financial burden incurred by new projects and a fair distribution of non-monetary costs and benefits throughout the region. Reliability is measured by water quality standards and the availability of an adequate raw water source. Low cost is based on both the initial construction cost per mgd and the annual operating cost. Social and economic equity is measured by the degree to which the program equally distributes costs and benefits in the region.

#### Program Descriptions — 4A, 4B, 4C

1980 — With Bloomington operating by 1980, adequate supplies to meet monthly water supply demands are available. Emergency restrictions would be implemented between 1980 and 1990 in Program 4C. Restrictions would also be neces-

sary for Programs 4A and 4B until additional projects come on line.

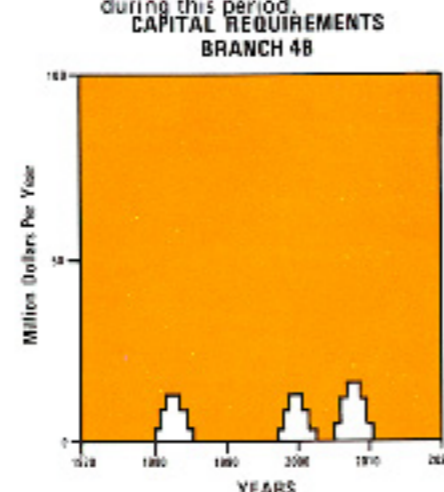
1990 — An interconnection between the Potomac and Patuxent Rivers through Montgomery County would supply up to 260 mgd to meet peak seven day demands through 2020 in Program 4A. A Potomac high flow skimming dam and lake project on Catoctin Creek in Loudoun County would supply up to 155 mgd to meet peak seven day demands and 130 mgd to meet monthly demands in Program 4B.

2000 — In Program 4A a Potomac high flow skimming dam and lake project on the Catoctin Creek in Loudoun County would supply 145 mgd. No projects are included in Program 4B for this time period. In Program 4C a Potomac high flow skimming dam and lake project on Goose Creek in Loudoun County would supply 20 mgd for peak seven day periods and

480 mgd to meet monthly period demands through 2020.

2010 — In Programs 4A and 4B, Sixes Bridge Dam and Lake Project on the Middle River in Frederick and Carroll Counties Maryland would supply 85 mgd. No projects are scheduled in Program 4C for this period.

2020 — In Programs 4A and 4B, Verona Dam and Lake Project on the Middle River in Augusta County, Virginia would supply 130 mgd. No projects are scheduled for Program 4C during this period.



**PROJECT DATA FOR BRANCH 4B\*\***

PROJECT	ULTIMATE		CAPITAL COST* \$ MILLIONS	ANNUAL* OM&R \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$MILLIONS)					
						THROUGH 1980		THROUGH 2000		THROUGH 2020	
	MONTH	7-DAY				LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
	SAFE YD. MGD	SAFE YD. MGD									
BLOOMINGTON	135	135	—	—	0	—	—	—	—	—	—
CATOCTIN	130	285	32.09	.19	5,600	2.0	0	45.9	26.1	78.2	58.7
SIXES BRIDGE	85	85	30.62	.03	0	0	0	0.0	0	52.2	23.4
VERONA	130	130	40.23	.07	0	0	0	0	0	45.9	22.7
SURPLUS	120	30									
TOTAL	500	665	102.94	0.29	5,600	2.0	0	54.5	26.1	176.3	110.0

\*AT COMPLETION

\*\*ALL FIGURES ARE IN 1974 DOLLARS

#### Program Rationale

This highly river regulation oriented program is concerned with quantity and quality of water, and with equitable distribution of monetary and non-monetary costs. It does not include wells or the new technologies. It responds to traditional practical and political considerations, although its acceptability is uncertain today.

Branch 4 represents a highly reliable water supply program and handles the seven day peaking problem in two different ways. In 4A interconnections, which only handle peaks of less than 30 days are included and in 4B and C, Potomac River high flow skimming projects, already on line to meet the monthly deficits are designed to also meet seven day peak deficits. Emergency restrictions are, however, used in 4A and 4B until 1981 and in 4C between 1980 and 1990.

Program 4A consists of an interconnection, a Potomac high flow skimming dam and lake on the Catoctin,

and Verona and Sixes Bridge Dam and Lake projects and meets the objectives quite well. All projects provide high reliability and low cost, as well as high quality water. With the exception of the interconnections which have high capital and operating costs associated with them, all the other projects have low capital and operating costs. On the question of social and economic equity, Catoctin is inside the service area.

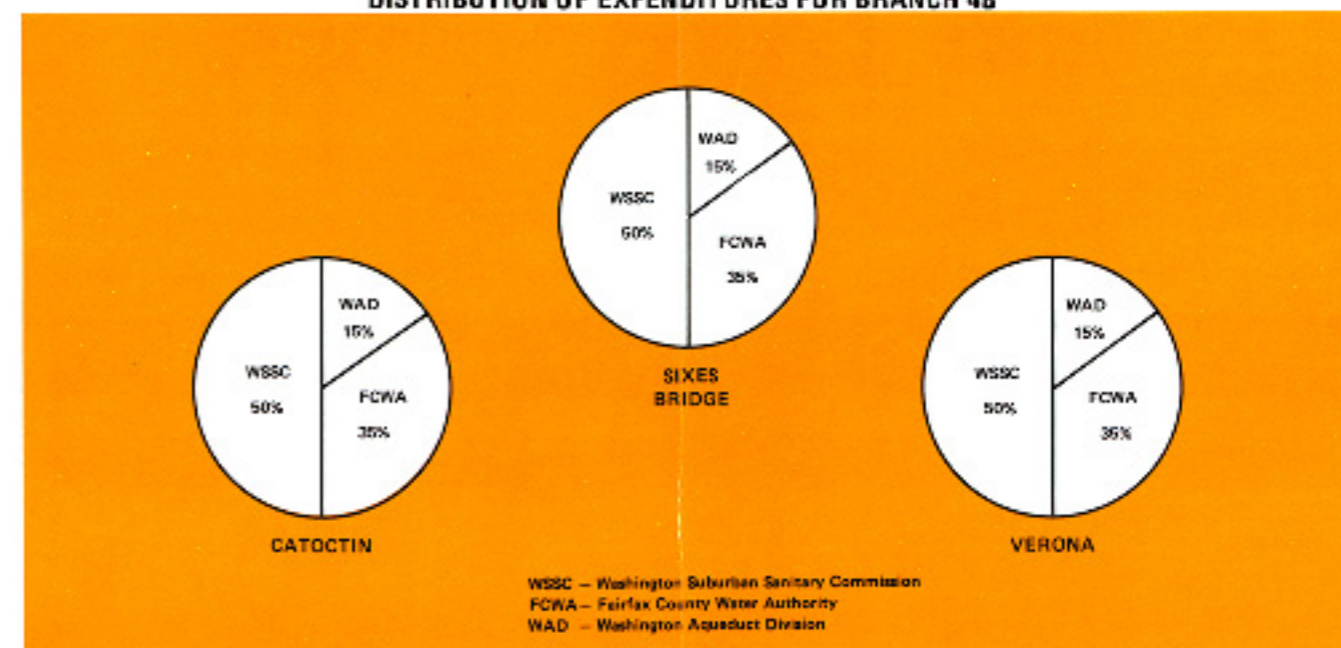
Program 4B consists of a high flow skimming dam and lake on the Catoctin and Verona and Sixes Bridge Dams and Lakes. The major difference between 4B and 4A is that in 4B the Catoctin project is designed to meet seven day peaks and eliminates the need for interconnections. Designing the Catoctin Creek project for Program 4B to meet the seven day as well as the 30 day deficits would be more costly both to construct and to operate than if it were designed to meet only 30 day deficits. It would, however, be less expensive than adding an additional project such as interconnections both in total cost and in cost per mgd.

Program 4C would consist primarily of a high flow skimming impoundment on Goose Creek designed to meet seven day and monthly demands. Goose Creek would provide reliability in terms of a low risk source and in quality of water supplied. It would have moderate to high capital costs due to its size but its operating cost would be low.

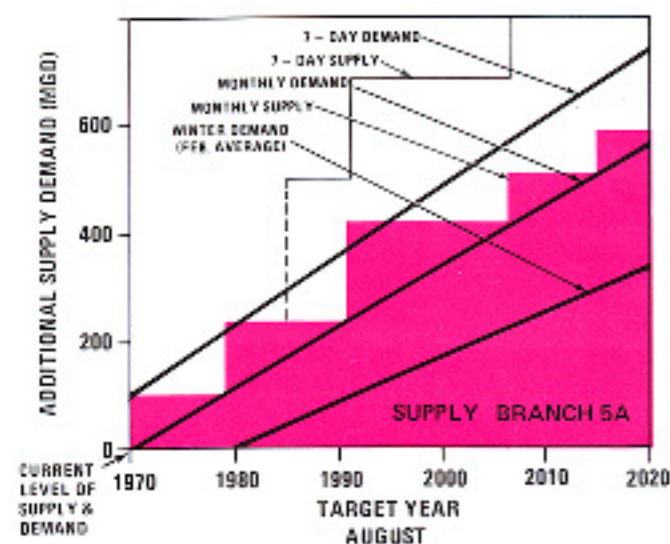
In comparing the three sub branches of Branch 4, all branches would equally meet the reliability objective. For low cost, Program 4B and 4C would probably be somewhat less expensive initially since an additional project for meeting the seven day peaking problems is not included. On the other hand operating costs would be incurred in Programs 4B and 4C to keep the high flow skimming impoundments full.

The reliance on local sources for the near term and on Verona and Sixes Bridge Dam and Lakes for later years complements social and economic equity considerations.

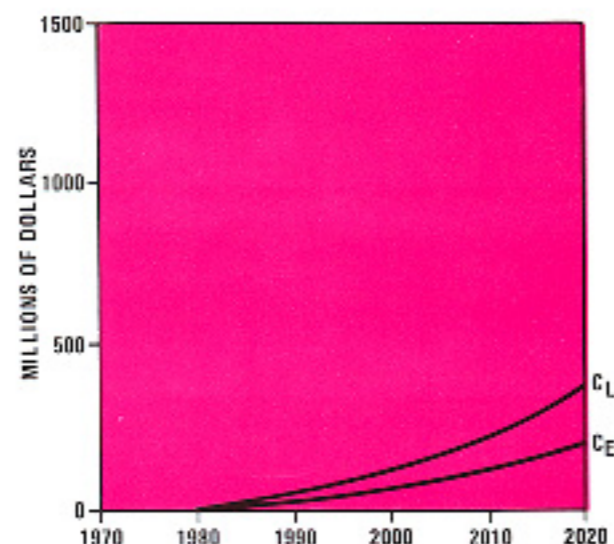
**DISTRIBUTION OF EXPENDITURES FOR BRANCH 4B**



# ADDITIONAL SUPPLY DEMAND VS. TIME BRANCH 5A



# CUMULATIVE EXPENDITURES FOR BRANCH 5A



# DECISION TREE - BRANCH 5A (AUGUST)



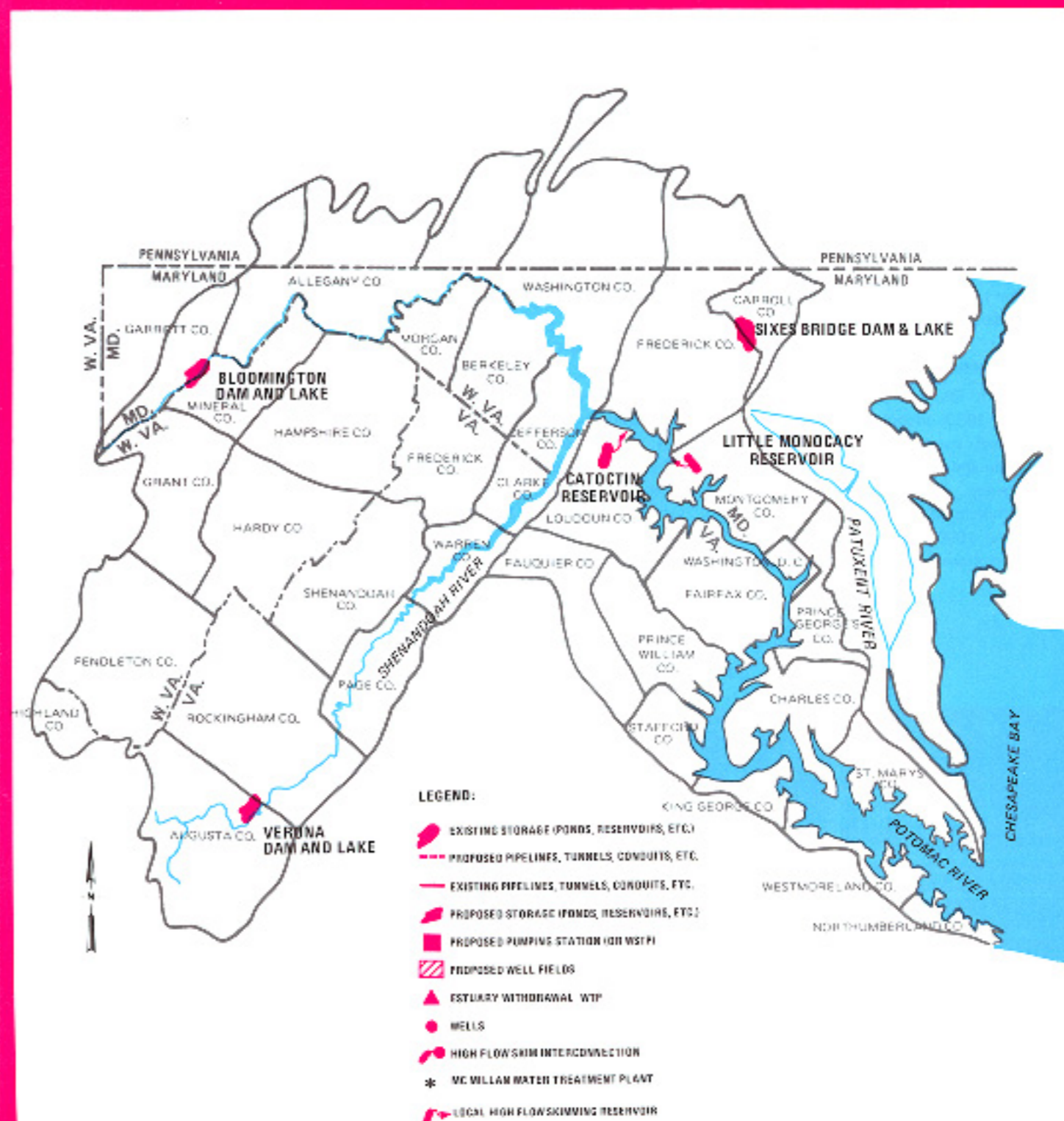
YEAR	1970		1980		1990		2000		2010		2020	
	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY
ADDITIONAL DEMAND (MGD)	-	-	135	155	245	280	355	410	465	535	575	665
ADDITIONAL SUPPLY (MGD)	120*	30*	255	165	255	435	445	625	530	710	615	795
ENERGY REQUIREMENTS (KWH/MG)**	-	-	0		0		0		0		10	

\* SURPLUS POTOMAC RIVER FLOW

\*\* AVERAGE

# BRANCH 5A

- RELIABILITY
- COST



**BRANCH NUMBER FIVE** — A program designed to satisfy the objectives of reliability and cost, as well as water supply.

Branch Five contains a mix of objectives traditionally held by those responsible for water supply. The assumptions behind these objectives are that a system is needed that best meets public health standards, imposes the least cost on the region, and provides a sufficient amount of water to support the projected growth and economy of the region.

#### Program Descriptions — 5A and 5B

1980 — With Bloomington operating by 1980, adequate supplies to meet monthly water supply demands are available. Seven day deficits will exist from 1981 to 1985 in Program 5B and will be met by restrictions as needed.

1990 — In Program 5A a Potomac high flow skimming dam and lake project on the Little Monocacy River in Montgomery

County could supply up to 270 mgd to meet peak seven day demands through 2020. In Program 5B Verona Dam and Lake Project would supply 190 mgd. This over supplies the monthly demand sufficiently to meet the seven day demand as well until 2000.

2000 — In Program 5A Verona Dam and Lake Project would supply 190 mgd. In Program 5B Sixes Bridge Dam and Lake Project would supply 85 mgd.

2010 — In Program 5A Sixes Bridge Dam and Lake Project would supply 85 mgd. In Program 5B a high flow skimming dam and lake project on the Catocin Creek in Loudoun County would supply up to 190 mgd to meet critical seven day demands through 2020 and 70 mgd to meet monthly demands.

2020 — In Program 5A a high flow skimming dam and lake pro-

ject on the Catocin Creek in Loudoun County would supply 85 mgd. No projects are needed in Program 5B.

#### Program Rationale

This program shares with the previous program the objectives of high reliability and low cost and is also a river regulation system. Program 5 is a low risk program and provides projects to meet the seven day peaking demand. Program 5A uses the Little Monocacy high flow skimming impoundment as a seven day peaking project, and in pro-

gram 5B the projects are brought on line earlier so that seven day demands are met with 30 day projects. Verona Dam and Lake and Sixes Bridge Dam and Lake with Potomac high flow skimming dam projects on Catocin Creek and Little Monocacy Creek make up Program 5A. These four projects meet the objectives of this program. All projects provide a reliable source of water of high quality.

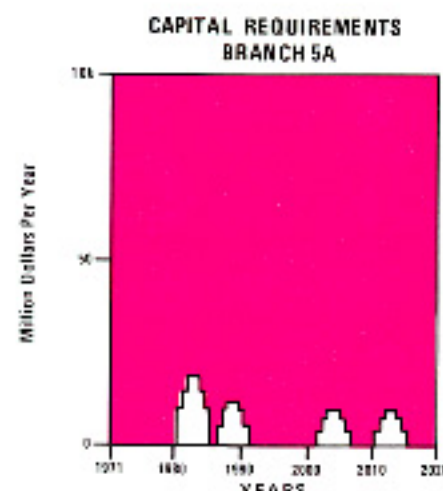
In addition, both Verona and Sixes Bridge Dam and Lake would indirectly benefit downstream water quality through dilution and the increase of waste assimilation capacities during critical low flow periods which in turn would improve the instream habitat quality. Each of these projects would provide much needed water surface area for forms of recreation not presently available in the area, such as fresh water boating, sailing, swimming and canoeing. In general these projects would complement environmental

quality. The Little Monocacy local impoundment and the Catocin Creek local impoundment would benefit water quality in the mainstem Potomac River, but their operation as seven day reservoirs would detract from their recreational potential due to the frequency and magnitude of anticipated drawdown. Also, these two project sites possess unique and appealing environmental and social values that would not be compensated by replacement with water surface area. Consequently, these two projects do not contribute greatly to environmental quality.

All the projects have low capital and operating costs since they are built to ultimate capacity for cost purposes. They also provide ample water in order not to limit growth.

Program 5B consists of Verona and Sixes Bridges and a high flow skimming impoundment on the Catocin

Creek. Unlike 5A, the Little Monocacy Project is not included but in its place Verona and Sixes Bridge have been implemented earlier and operate so that monthly supplies also meet seven day peaks. Later in the program when the Catocin Project is built it would be used for both monthly and seven day peak demands. The operating rules for Verona and Sixes Bridge would be changed to provide only monthly supplies. Program 5A complements the objectives well. In comparing Program 5A and B, both have high reliability and provide the flexibility to meet unforeseen growth demands since they rely on larger projects. Program 5B is lower in cost than 5A. In 5A an additional project is included to specifically meet seven day peak deficits, while in 5B projects are implemented earlier and operated to meet seven day peak deficits.



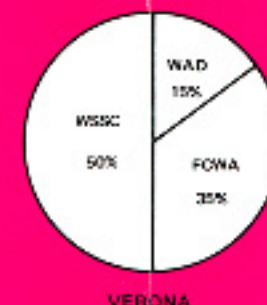
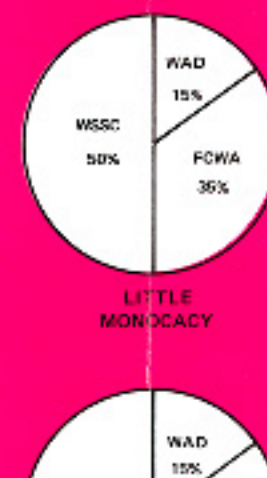
**PROJECT DATA FOR BRANCH 5A\*\***

PROJECT	ULTIMATE		CAPITAL COST* \$ MILLIONS	ANNUAL* OM&M \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$MILLIONS)					
	MONTH SAFE YD. MGD	7-DAY SAFE YD. MGD				THROUGH 1990		THROUGH 2000		THROUGH 2020	
						LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
BLOOMINGTON	135	135	—	—	0	—	—	—	—	—	—
LITTLE MONOCACY	0	270	60.44	.64	10,200	4.2	0	95.1	98.1	171.2	130.7
VERONA	190	190	40.23	.07	0	0	0	61.0	20.6	100.8	61.8
SIXES BRIDGE	85	85	30.62	.03	0	0	0	0	0	41.3	21.7
CATOCTIN	85	85	32.09	.19	5,600	0	0	0	0	23.6	9.8
SURPLUS	120	30									
TOTAL	615	795	163.38	0.93	15,800	4.2	0	142.1	78.7	336.9	224.0

\*AT COMPLETION

\*\*ALL FIGURES ARE IN 1974 DOLLARS

**DISTRIBUTION OF EXPENDITURES FOR BRANCH 5A**



WSSC — Washington Suburban Sanitary Commission  
FCWA — Fairfax County Water Authority  
WAD — Washington Aqueduct Division

# CHAPTER 7

## THE NEW YORK METROPOLITAN AREA



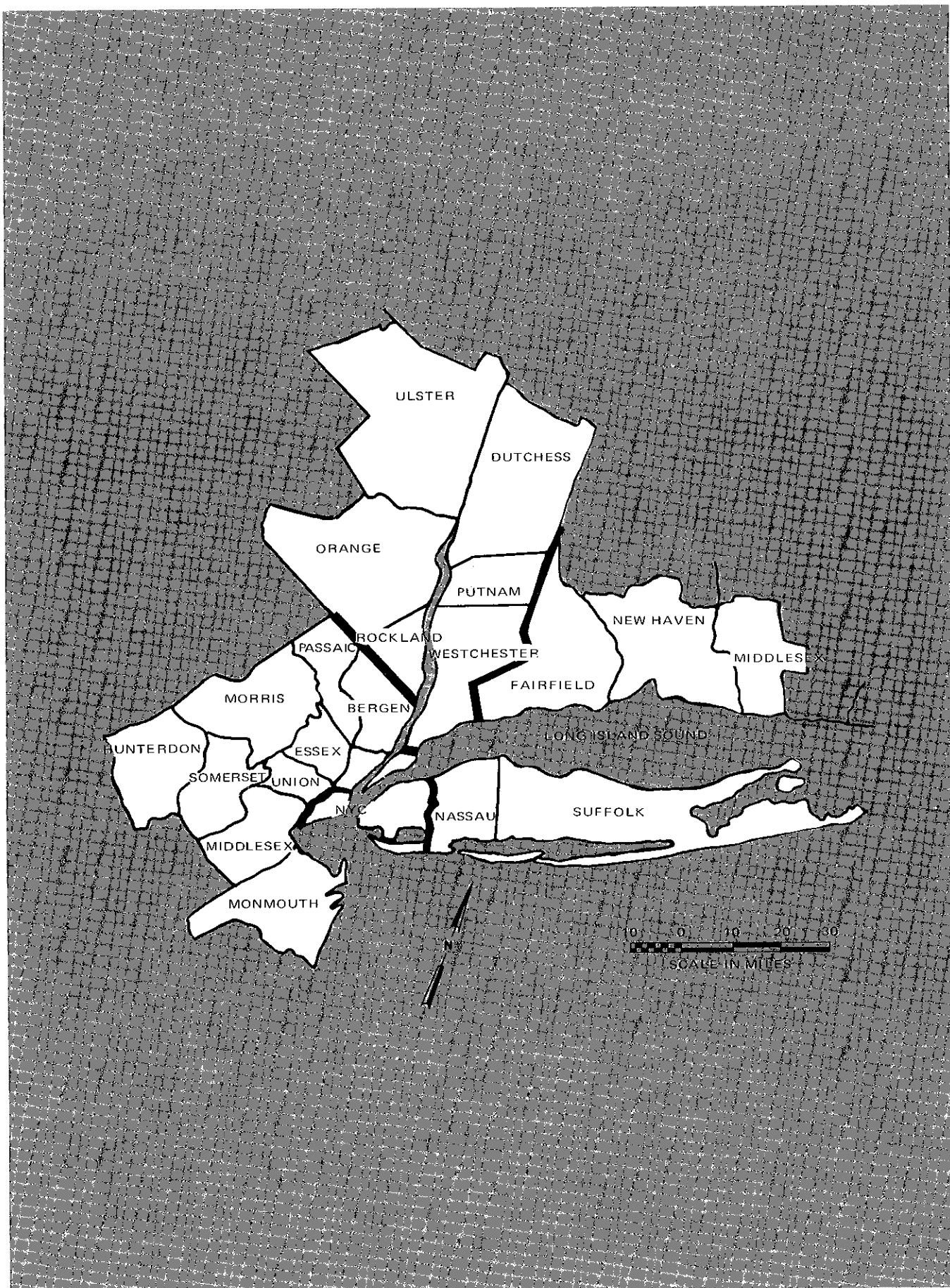


FIGURE 7-1. NEW YORK METROPOLITAN STUDY AREA.

## CHAPTER 7: THE NEW YORK METROPOLITAN AREA (NYMA)

### BACKGROUND

The New York Metropolitan Area (NYMA) consists of the New Jersey Counties of Passaic, Bergen, Hudson, Essex, Morris, Hunterdon, Somerset, Middlesex, Union and Monmouth, the Connecticut Counties of Fairfield, New Haven and Middlesex west of the Connecticut River and the New York Counties of Rockland, Orange, Ulster, Westchester, Putnam, Dutchess, Nassau and Suffolk, and New York City. This study has, to date, defined the regional water supply problems and has developed and evaluated potential solutions to them. Analysis and interpretation of data from a number of engineering, hydrologic, environmental, social, economic and institutional studies has provided the input on potential water supply projects and programs used as the basis for this chapter. These source studies are described in the Annotated Bibliography. As with the other two most critical areas, this information has been published and distributed widely to gather as much public and agency reaction as possible. Close coordination has been maintained with state and local agencies and various elements of state plans have been built into the planning process.

As a result of studies to date, a number of preliminary conclusions have become evident concerning public decisions that must be made in the near future. The water supply planning for the NYMA is at a critical stage. Recent actions regarding the Tocks Island Dam and Lake Project have resulted in a recommendation for deauthorization. If water supply demands are to be met, critical choices must be made now on alternative sources for detailed study and recommendation of projects to Congress for authorization. This chapter presents the major alternatives available for selection.

### AREA PROFILE

The NYMA covers 9,345 square miles and includes 26 counties in the three States (see Figure 7-1). It includes not only the city of New York, but other municipalities with populations exceeding 150,000 such as Newark and Jersey City in New Jersey, Yonkers in New York and Bridgeport and New Haven in Connecticut. The area being studied also includes several hundred smaller communities.

The NYMA is by far the most complex of the three most critical areas. The study area covers the most densely populated area of the Nation's most densely populated State (northern New Jersey). It contains the Nation's largest city (New York), but other portions are almost rural in nature.

It includes areas where industrial complexes are packed shoulder to shoulder, and areas where business and commerce are stacked in 100-story skyscrapers. It contains the Nation's largest concentration of financial, trade, professional, business and communication services. Manufacturing, however, provides the major employment. Yet, the NYMA also involves areas where farming is a major business.

Population projections for the area have been made by many agencies. Although they were made at different times, extend over different periods, and do not cover exactly the same area, they agree that the area faces a major population increase by the year 2020. Present water supplies will be inadequate to serve the needs of a growing population.

The population projections used in this report are based on the OBERS 1972 Series E projections, prepared by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. Series E projections are based on long term nationwide attainment of "replacement level fertility" reflecting gradual reduction in annual rates of increase in population. The OBERS projections for each state have been broken down for areas within the NYMA proportional to the distributions used by each state for its own projections. The 1970 population and projections are shown in Table 7-1.

### WATER DEMANDS

Total water use in 1970 in the NYMA exceeded 2.7 billion gallons per day. Per capita use varied widely in the study area. The non-industrial per capita use ranged from 70 gallons per day (gpd) to over 200 gpd and aver-

TABLE 7-1  
POPULATION PROJECTIONS 1970-2020 - NYMA  
(in millions)

	1970	1980	2000	2020
Northern New Jersey	5.1	5.8	6.9	7.9
New York City	7.9	8.0	8.4	8.8
Suburban New York State	4.3	4.9	6.5	7.7
Southwestern Connecticut	1.6	1.8	2.1	2.5
TOTAL	18.9	20.5	23.9	26.9

aged 135 gpd. Publicly supplied industrial use, on a per capita basis, is even more variable, ranging from almost zero in some areas to 50 gpd in the Central Naugatuck Valley of Connecticut. In New Jersey, publicly supplied industrial use accounted for 13% of the total water used. In New York, it represented 3% and in Connecticut 36%.

Projections of population, economic activity, residential density, domestic water use, and water conservation measures indicate that total water demand in the NYMA will exceed 5.1 billion gallons per day by 2020 (see Table 7-2). Water conservation devices were assumed in 25% of all new homes, reducing water use by 18 percent for flush toilets, 7 percent for showers and 1 percent for washers.

Future industrial demand is a major element of total demand. It is assumed that all additional industrial water requirements in the future will be publicly supplied, so that industrial

licly supplied water in 1970 to 36% in 2020.

Furthermore, the level of future demand is highly sensitive to the rate at which industrial recirculation and water saving technological change are assumed to increase. A uniform rate over the area has not been assumed as part of the base case for two major reasons:

1. The study boundaries cross three independent political subdivisions, New Jersey, New York and Connecticut.
2. Industrial activity, while important in the Connecticut and New York portions of the study area, is not the core of their economies. As a result, these states may be much more likely to impose early action controls on water use in industry than a state whose economic base is primarily and solely industrial, such as New Jersey, and northern New Jersey in particular.

The rate of improvement in recirculation and technology can, however, be influenced by deliberate public policy, with great effect. For instance, Table 7-2 assumes that such improvements will reduce the amount of water used for a given level of industrial output in 2020 to approximately one-half of the 1970 amount. If a more stringent public policy were adopted, the amount of water for a given level of industrial output could be reduced to one-third the 1970 amount, and New Jersey's deficit in 2020 would be decreased by 415 mgd, or one-half. The results for the other states would not be as dramatic since there is less industrial water use than in New Jersey.

## AVAILABLE WATER

The complexity of the NYMA is reflected in the results of initial studies. More than 100 separate water supply projects to draw on available water sources were studied and found to be technically feasible. Sources as distant as the Susquehanna River and the Great Lakes were investigated.

Obviously, these feasible sources had to be narrowed down to a more manageable number for further study. The early winnowing process was primarily one of screening the sources to see which ones could supply the large amounts of water necessary as close to the user areas as possible for reasons of equity and cost of development. Sources outside the overall NEWS Study area were examined, and preference was given to sources within the NYMA. The following sources passed the screening process.

### Hudson River

The largest single water resource within reach of the study area, the Hudson River, has an average flow exceeding 12,000 mgd at Poughkeepsie. Beginning in the Adirondack Mountains in northern New York, it flows southerly 147 miles to Troy, New York, and then becomes tidal for 153

**TABLE 7-2**  
**WATER SUPPLY SUMMARY - NYMA**  
(millions of gallons a day)<sup>1</sup>

	1970	1980	2000	2020
<b>NEW YORK</b>				
Average Annual Water Demand	1860	2110	2490	2970
Potential Local Supplies <sup>2</sup>	1760	1960	2040	2130
Water Supply Deficits	100	150	450	840
<b>NEW JERSEY</b>				
Average Annual Water Demand	680	820	1200	1650
Potential Local Supplies <sup>2</sup>	640	700	800	820
Water Supply Deficits	40	120	400	830
<b>CONNECTICUT</b>				
Average Annual Water Demand	220	290	360	500
Potential Local Supplies <sup>2</sup>	220	250	260	260
Water Supply Deficits	0	40	100	240

<sup>1</sup> Rounded to the nearest 10 mgd.

<sup>2</sup> It is assumed that demands are initially met by development of local supplies over time, until the maximum capability of those supplies is reached.

miles to its mouth in New York Harbor.

#### **Delaware River**

One of the largest rivers on the east coast, the Delaware River has a drainage area of 6,780 square miles and an average flow of 7,600 mgd at Trenton, New Jersey. This major river flows through the States of New York, New Jersey, Pennsylvania and Delaware.

#### **Housatonic River**

The Housatonic drains much of the western part of Massachusetts and Connecticut and has an average flow of 1,600 mgd at Stevenson Dam. It is widely used for recreation, power production, and industrial water supply and waste disposal.

#### **Connecticut River**

The Connecticut River drains much of Vermont and New Hampshire, the western part of Massachusetts, and Connecticut. With an average flow of 10,300 mgd at Thompsonville, Connecticut, the River has been developed extensively for hydroelectric power and industrial water use, but the main stem has not been used for public water supply.

#### **Other Sources**

Other sources of water supply in the NYMA are the smaller Passaic and Raritan Rivers in New Jersey and the ground water aquifers of Long Island and southern New Jersey. Desalinization of brackish water or sea water is also under consideration, although it poses questions of cost, energy requirements and environmental effects. Conservation measures and devices have also been addressed, and if implemented to a degree greater than already assumed could reduce the demand supply imbalance.

### **WATER SUPPLY PROGRAMS**

Alternative programs, comprised of various projects, were designed prima-

rily to meet the water demand of the NYMA. However, they were formulated in such a manner as to also recognize and complement various other objectives voiced by concerned residents of the area.

The evaluation process is a detailed technical assessment of the effects of a project on the NYMA and on the additional objectives. A preliminary application of this lengthy procedure furnished the wealth of detailed information that led to the formulation of the decision tree (see Figure 7-3), which presents five possible courses of regional action.

The Congressionally authorized Tocks Island Lake Project has been recommended for deauthorization by the Corps of Engineers. However, since Congress has not yet acted on the recommendation, it has been included as a potential project on two Decision Tree branches.

The five branches of the decision tree were chosen from among the large number of possible project combinations that would, in a technical sense, meet the growing water demands of the area through the year 2020. The branches are shown to indicate how various projects, when combined, could assist to satisfy one or more local objectives, in addition to water supply. They also demonstrate how more than one source of water can be used within the framework of a regional program. Examples include early New Jersey development in the Raritan River Basin and development of both the Hudson and Delaware Rivers for regional supply. The planning process is continuing. However, choices will have to be made soon if the risk of shortage is to be lessened. Recent actions regarding Tocks Island Lake Project increase the urgency to make choices among alternatives.

What has become evident, as a result of the formulation of these regional programs, is that water source development is urgently needed, and critical decisions should be addressed immediately.

Studies to date indicate that:

1. The Hudson River is a major regional source essential for near-term water supply needs for Southeastern New York and longer-term needs for Northern New Jersey. The long lead time necessary for project implementation, on a scale which will meet the future needs of this area, requires that choices be made soon so that more detailed studies relating to the manner in which the Hudson River might be developed can be initiated.
2. The Delaware River is a major potential source. A choice must be made concerning continued examination of plans to develop water supply from the Delaware River in view of the recommended deauthorization of the Tocks Island Lake Project.
3. If the Delaware River is developed to meet needs in northern New Jersey in the early years, it will still be necessary to utilize, in a more limited way, the Hudson River in the later decades. However, due to the complex issues arising over the possible future use of the Hudson for northern New Jersey (e.g., institutional, environmental), state and local entities should soon address the choices for utilizing the Hudson.
4. Delayed development of the Delaware River will require that the Hudson River be developed more intensively in the near term for northern New Jersey. This will forestall the need to go to the Delaware, but is not likely to eliminate it.

Feasibility analysis of the potential sources indicates that there are several ways to develop the Hudson to provide for the needs of the study area. The alternatives include high-flow skimming from the east or west banks in the vicinity of Hyde Park-West Park; river regulation by reservoirs and diversion at Hyde Park-West Park; development of the upper Hudson with reservoirs and tunnels supplying water by gravity, or any combination of these.

The New York City water supply system current use exceeds its safe yield and needs additional water supply now to avert the risk of system failure in the event of a drought. Projections based on long term trends indicate a 1980 deficit of 150 mgd for the New York portion of the study area.

If the development of the Hudson is delayed, it may be necessary to use the Long Island ground water aquifer to meet the near-term needs of New York City and Nassau County. Regardless of which source is initially developed, the Hudson must ultimately be developed for long-range demands, since the yield of the Long Island aquifer can only meet short-term needs.

Further, the analysis shows that if the Delaware is to be used as a significant source for meeting the water supply deficits in New Jersey, either the Tocks Island Lake Project must be built or a number of smaller upstream reservoirs will be necessary to provide storage for downstream releases. Releases would be made for New Jersey and Pennsylvania users and to maintain minimum flows in the River and into the estuary. If this is done, then the Delaware can be regulated to provide up to 300 mgd.

The development of intra-state projects in conjunction with these major inter-state sources will still be necessary. Intra-state developments, while usually smaller in scale, also require early action because of the long lead times usually associated with implementation of any project. In New Jersey, for example, the Passaic Plan (Two Bridges) can still be developed for water supply. However, if the development is to be timely, the choice to include the water supply component must be addressed very soon. The implementation of industrial and domestic conservation to the degree assumed in the projections also requires early action.

The following is a preliminary list of potential projects that form the elements for the branches of the decision tree.

*Spruce Run-Round Valley* — The yield of the Raritan River could be increased by 80 mgd through full use of the existing Spruce Run and Round Valley Reservoirs, the Hamden pumping station and the force main to the Round Valley. An improved outlet from Round Valley Reservoir is being built to make use of this additional supply. Withdrawals for treatment and transmission to areas of use can be accomplished downstream at either new or existing intake sites.

*Confluence Reservoir* — This project has been considered by the State of New Jersey as one element of a proposed plan to meet its water needs through development of intra-state sources. The plan, which has not been officially adopted, is under study by the state. The Confluence project would include a one billion gallon reservoir at the confluence of the north and south branches of the Raritan River, a pumping station at the reservoir, and a force main to Round Valley. The drainage area

above the proposed dam site totals 466 square miles. Of this, some 41 square miles are already regulated by Spruce Run Reservoir and an additional 106 square miles are tributary to the Hamden pumping station connected to Round Valley Reservoir. Development of the additional drainage area would increase the upper Raritan River system safe yield approximately 50 mgd.

*Tocks Island Lake Project* — (Frenchtown-Round Valley-Raritan River) This project now recommended for deauthorization would have used a tentative allocation of 300 mgd to New Jersey from the Tocks Island Lake. Releases from the lake would have been captured downstream by diversion facilities at Frenchtown, consisting of a 360 mgd pumping station and an aqueduct to Hamden. Portions of the water could have been pumped to the Passaic River Basin, or would be allowed to flow in the Raritan River channel. Water could also have been pumped to Round Valley from Hamden when necessary.

*Delaware Diversion* — (High-Flow-Skimming to Round Valley) Delaware River water would be diverted at Frenchtown each year during six months of high flows and stored in Round Valley. The project would operate to provide New Jersey with 100 mgd, in addition to that currently available through the Delaware and Raritan Canal. Arrangements would be included for returning 40 mgd to the Delaware during dry weather to compensate for wet weather withdrawals. The intake and pumping station at Frenchtown, and the aqueduct to Hamden would be similar to those for the project described in the preceding paragraph. A second force main to Round Valley would be required, however. (This project could have preceded the Tocks Island Lake Project and could have been in effect, a first stage development of the latter project.)

#### *Tocks Island Lake Project Exchange —*

This project would have used New Jersey's tentative allotment from the Tocks Island Lake project for Delaware River control. As mandated by the Supreme Court decision of 1954, the New York City system must maintain Delaware River flows of 1130 mgd at Montague, New Jersey. In this plan, New Jersey would not withdraw its 300 mgd allocation of Delaware River water from the Tocks Island Lake Project but would allow this water to flow down river for flow regulation. The New York City system would be required to release from its upstream reservoirs a maximum of 830 mgd rather than 1130 mgd in low flow periods. The water thus retained in upstream reservoirs (approximately 300 mgd) would then be available to meet the needs of northern New Jersey as well as the New York City system. For New York City there would be no construction required. Water could be delivered to northern New Jersey by either of two alternatives; a pipeline from Shaft 4 of the Delaware Aqueduct to northern New Jersey, or a tunnel from Kensico Reservoir to Great Notch, New Jersey.

*Two Bridges Reservoir —* The State of New Jersey has approved a comprehensive plan for flood control for the Passaic River Basin, with the possible inclusion of water supply and other purposes, to include the construction of a reservoir, a dry detention area, and channel improvement. Water supply could be developed from a 26 billion gallon reservoir to be located near the confluence of the Pompton and Passaic Rivers at Two Bridges. The upper 7.5 feet would be used for flood control and the balance for water supply purposes, with an estimated yield of 100 mgd, disregarding ground water recharge. The reservoir would be built with dikes to exclude poor quality runoff from the upper Passaic River in favor of better quality water diverted by gravity from the Pompton River.

An alternative to Two Bridges which utilizes flows by pumped diversion from the Ramapo, Pompton and Passaic Rivers into the Wanaque Reservoir, would increase dependable safe yield by 26 mgd to 80 mgd. This option is currently under consideration by major purveyors in the area.

*South Jersey Groundwater —* South of the fall line between Trenton and Raritan Bay, New Jersey, the topography is relatively flat, resting upon coastal deposits dipping southeast into the Atlantic Ocean. Wells tapping the Cohansey and Kirkwood sand aquifers in the coastal area produce large quantities of water with the most abundant supplies close to the ground surface. Natural recharge of the coastal aquifers averages 20 inches per year, or 0.1 mgd per square mile. While the water ultimately may be needed for cities and for industrial and agricultural developments in southern New Jersey, present demands are small. As long as arrangements could be made to meet future water needs as they developed in the southern part of the State, the water could be exported advantageously to more densely populated regions in northeastern New Jersey.

*Hudson River Development —* Hudson River water would be diverted during high flows. An intake and pumping station would be constructed to divert water into the existing water supply systems to supplement or replace releases from existing reservoirs. This procedure would maintain higher reservoir levels for use during periods of low flow thereby increasing the safe yield. The safe yield of the existing NYMA systems could be increased by approximately 600 mgd without additional upstream reservoir development. Possible projects include:

1. Hudson-Ramapo Diversion — Hudson River water would be diverted to the Ramapo River to supplement

the Wanaque supply to the North Jersey District Water Supply Commission and the Hackensack Water Company. Water might also be provided to Orange and Rockland Counties in New York. The project would include an intake and pumping station at West Park, New York (opposite Hyde Park), a 31-mile aqueduct to the headwaters of the Ramapo River at Harriman, a pumping station at Pompton Lakes, and a force main to Wanaque Reservoir. A filter plant proposed by the North Jersey District Water Supply Commission at Wanaque would have to be enlarged to take care of the greater output. Except for seven miles of tunnel under Newburgh, the West Park-Harriman Aqueduct could be cut-and-cover construction.

2. Hudson Diversion-Hyde Park — Water would be diverted and treated in the vicinity of Hyde Park. The water supply facilities would include a 50-mile tunnel 20 feet in diameter to Kensico Reservoir, one of New York City's reservoirs in Westchester County. The pumping stations and treatment facilities could be built in stages as needed, but the intake and tunnel would be constructed to ultimate capacity. Beyond the year 2000, Hinckley Reservoir could be enlarged and Schaghticoke Reservoir could be added to provide an increased yield. The existing Sacandaga Reservoir power pool could also be reregulated to increase yield or to decrease the rate of high flow diversion. Such upstream developments can increase safe yield up to approximately 1500 mgd. Requirements for Dutchess and Putnam Counties could be diverted enroute. Nassau and Westchester Counties would be supplied from the City system. Northern New Jersey could be supplied using a 12-foot diameter tunnel from Kensico Reservoir.

3. Hudson Diversion-West Park — Water would be diverted and a water

supply treatment plant would be built in stages on the west side of the Hudson River at West Park. Water would be pumped from the plant through a 15-mile, 20-foot diameter tunnel to the point west of Poughkeepsie where New York City's Delaware and Catskill aqueducts cross at Shaft 4.

Water for New York counties would be transmitted by tunnel on the West Bank to the vicinity of Spring Valley in Rockland County and thence under the Hudson River to the Kensico Reservoir and the New York City system. Requirements for Ulster, Orange and Rockland Counties could be diverted enroute. Nassau and Westchester Counties would be supplied from the City system. Water for New Jersey could be provided via pipeline from the Shaft 4 area or by connection to the tunnel in Rockland County. The project would be operated as a high flow diversion until water needs exceeded its yield. Then after the year 2000, upstream reservoirs such as an expanded Hinckley Reservoir or Schaghticoke Reservoir could regulate flows to enable a year round diversion of Hudson flows. The existing Sacandaga Reservoir power pool could also be reregulated to increase yield or to decrease the rate of high flow diversion. A connection to Ashokan Reservoir from the tunnel could be added to increase yield and operational flexibility. With the addition of the Ashokan Reservoir connection, the Catskill Aqueduct and the lower portion of the Delaware Aqueduct would be looped, allowing portions to be shutdown for repair or maintenance. Yields for this project range up to approximately 1500 mgd with upstream development.

#### 4. Hudson Gravity Aqueduct Development — Water would be

diverted and a treatment plant and pumping station would be built at Hyde Park or West Park connected by a tunnel to Kensico Reservoir, as described above. Beyond the year 2000, Hinckley Reservoir could be expanded and new reservoirs constructed at Forestport and McKeever in the Black River Basin, which drains into Lake Ontario. These sources would be linked by tunnels and connected to Kensico Reservoir by a 175-mile gravity flow tunnel providing up to approximately 1500 mgd in increased safe yield. This gravity tunnel would connect with Ashokan Reservoir (looping the Catskill Aqueduct) and would pass through Hyde Park or West Park where the initial high flow diversion pumping station would have been located. New Jersey's needs would be met with a 12-foot diameter tunnel.

*Trap Falls Reservoir —* (Lower Housatonic River Diversion to Trap Falls.) This project would be a run of the river diversion of 40 mgd from the Housatonic River. The project would firm up the New Haven Water Company and Bridgeport Hydraulic Company systems, thus enabling them to transfer water from existing sources to adjacent systems in Western Connecticut.

*Housatonic River Development —* The Housatonic Basin could provide 160 mgd by converting existing power generation storage to water supply. The top 10 feet of storage in Candlewood Lake and the top 50 feet of storage in Lake Lillinonah would be used for water supply releases rather than for power generation as in the past.

Safe yield from the Housatonic Basin could further be increased by about

320 mgd through construction of additional storage reservoirs above Lake Housatonic, such as Robbins No. 2 at Falls Village, Connecticut and Konkapot No. 2 near Housatonic, Massachusetts.

*Connecticut River Development —* This project is a run of the river diversion which would deliver 90 mgd through a pipeline from the Connecticut River at Middletown, Connecticut, to New Haven following treatment at Middletown. Upstream storage of 16 billion gallons would be required.

*Long Island Exchange —* This project proposes that during normal, non-drought years, Long Island would be partially supplied by the surplus of the New York City system. This would permit natural recharge of the Long Island aquifer, with minimal pumping from the aquifer during normal and wet years. During dry periods, 150 mgd of Long Island groundwater would be furnished to New York City, and Nassau County over and above the requirements of Suffolk County communities. However, Suffolk's needs around 2020 will have increased to the point where this project would have to be phased out as a regional source.

*Long Island Total Resource Management Program —* This project is a water resource management program which combines techniques such as water conservation devices and methods; recharge of treated wastewater to the aquifer through wells, basins, and spray irrigation of farmlands; recirculation devices; and surface water augmentation (lakes and streams) with

treated wastewater. These devices under a carefully defined and coordinated program would meet the needs of Nassau and Suffolk Counties through wise use of internal resources or in combination with outside sources such as the Hudson River projects.

There are many technological uncertainties that must be resolved before these methods could be implemented. For example, the Corps of Engineers and the New York State Energy and Research Development Authority are engaged in a joint study to develop a program that would demonstrate the integration of water supply, wastewater management, power generation and land use control. One aspect of this investigation addresses the efficiencies and technologies related to application of treated wastewaters via land application systems to ultimately perfect groundwater recharge techniques. The construction of thousands of storm-water recharge basins throughout Long Island by Nassau and Suffolk Counties constitutes the beginning of such a total Resource Management program.

*Metering* — The implementation of universal metering in New York City over the period 1980-2000 might lead to a saving of an estimated 125 mgd by 2020. This yield, however, is not certain. Consequently, a metering demonstration project is advisable before the yield of a full scale project is established.

*State Plans* — The Connecticut Plan of Conservation and Development con-

tains policies and project proposals specifically pertaining to water supply. The Plan consists of numerous localized groundwater and surface projects. The following constraints were used by the State to determine suitable projects:

1. No streams were considered for water supply which had sewage discharges within the watershed.
2. No major relocations were allowed.

By the year 2020, the State Plan will provide an additional 172 mgd to Connecticut's water supply. Of this 172 mgd, approximately 44 mgd will come from groundwater development and the remainder from surface projects. While there are over a dozen surface projects, four will supply the bulk of water. The diversion of the Shepaug River in Roxbury will supply 52 mgd, the Trumbull Dam of the Poquonock River will add 6.5 mgd, the expansion of facilities at Lake Whitney will further add 15 mgd and the NYMA portion of the State will receive 13 mgd from the West Aspetuck River.

Policies necessary to implement this plan include preservation of future reservoir sites, management of watersheds to protect water quality at those sites, continuing to prohibit direct waste discharges into streams tributary to public water supplies and continuing to disallow the building of water supply facilities which would be fed by wastewater receiving streams.

NEWS projects for the Connecticut portions of the NYMA indicate a greater demand than that upon which the Connecticut State Plan is based. Should these demands materialize the Connecticut plan would need to be modified.

As discussed in connection with Round Valley and Confluence Projects, the State of New Jersey is considering a plan to meet its future needs through intensive development of instate sources. A plan, which has not been officially adopted at this time, includes increased interconnections among local systems, indirect use of treated wastewater, further development in the Raritan and Passaic River Basins, and development in the Manasquan River Basin. Projects include Six Mile Run and Washington Valley Reservoirs and expansion of the existing Round Valley Reservoir. Other possibilities include increasing the capacity of the Delaware and Raritan Canal and highflow skimming of the Passaic River at Two Bridges into Wanaque Reservoir.

For long-term needs the State will also require water from among the following alternatives: alternative Delaware River developments; groundwater in southern New Jersey; or water from the Hudson River.

The Temporary State Commission on the Water Supply Needs of Southeastern New York has submitted its final report with legislative and program recommendations to the Governor and Legislature of the State of

New York. The Commission recommends that a regional corporation take over existing regional water supply facilities, develop new facilities and operate these in an integrated manner, and limit source development to the Hudson River Basin. As an alternative to a regional corporation, the Commission recommended the creation of a State water supply agency. This agency would be limited only to new source development in the Hudson River Basin, and would preferably lease operating responsibilities to New York City to integrate regional facilities.

The only specific project proposal is for high-flow skimming with a pumping station at Hyde Park and a tunnel to Kensico Reservoir operated to provide a yield of 280 mgd. Any further development would be contingent upon universal metering in South-eastern New York, particularly in New York City. Any additional source development would require specific legislative authorization.

The plans for New York and New Jersey are not included as separate decision tree branches because they are not official. However, elements of the plans are included in combination with other projects. Should these plans be officially adopted, they will be included in their entirety in future planning.

## DECISION TREE DEVELOPMENT

There are several key factors that determine a project's selection or omission for a particular branch on the Decision Tree. In some cases, the selection of one project on a branch may preclude another possible project because of the development or use of common sources of supply or transmission facilities.

- *Project constraints.*

Many of the listed projects would use the same sources or transmission systems and, consequently, some projects could not be included together in the same regional programs or possibly in the same time frame of a regional program. For instance, yields for both the Tocks Island Lake Project with a diversion at Frenchtown and Tocks Island Lake Project Exchange would depend on the 300 mgd that could have been available from the Tocks Island Lake Project. The nature of the Tocks Island Lake Project Exchange would be to eventually phase out the exchange as New Jersey demand increases leaving the Tocks Island Lake Project for later time frames.

Another instance includes the Delaware Diversion which would be a high-flow skimming project located downstream of the Tocks Island Lake Project site. The Delaware Diversion could be built to skim high-flows and would be a complete project in itself. But if the Tocks Island Lake Project were to be built, the Delaware Diversion would be discontinued since most of the high-flows would be impounded by Tocks Island Lake. The Delaware Diversion, however, could be

built and used until that time as the Frenchtown diversion facilities and transmission line are also components of the Tocks Island Lake Project.

There is also the case of Delaware Diversion and Confluence Reservoir where both projects use the same storage capacity in Round Valley Reservoir, and either project would preclude use of the other. The Tocks Island Lake Project Exchange would not be feasible with any of the Hudson River high-flow skimming stages because the high-flow skimming and the Delaware Diversion both utilize excess capacity of the New York City system aqueducts to provide additional water supply yield. However, the Tocks Island Lake Project Exchange could precede the Hudson River high-flow diversion.

- *Implementation time.*

Time for building projects is related to the size of the job, the number of operations that can be carried out simultaneously, and the price one is willing to pay for speed.

The time required for public approval, funding, and acquisition of land is an additional consideration.

Many of the projects may require the formation of an interstate or intercommunity agreement that may require additional time.

Table 7-3 indicates the earliest time that these projects could be delivering water.

## DECISION TIMING

The timing involved for implementation of each project is an important factor which must be considered when projects are selected for inclusion in a plan. The schedules of implementation shown in Figure 7-2 are for the early action projects in each branch of the Decision Tree or others that require special consideration because of long lead times or technical uncertainty. Figure 7-2 illustrates the point in time at which decisions should have been made to overcome the current deficit and to reduce the risk of shortages in the early time frame. Some decisions have already been made on Round Valley and Confluence but for the remaining projects the time has past when initial decisions should have been made. This means that the region will experience the risk of water supply shortage for a number of years.

other reservoirs since the State of New Jersey has acquired the land and developed preliminary design drawings for the reservoir. It may not be possible to bring this project on line by 1980; however, it could be operational shortly after 1980, and restrictions on use could be imposed until it becomes operational.

*The Delaware Diversion* is one of the first projects on Branches 3, 4 and 5. It is a high-flow skimming project on

the Delaware River, which will require a lead-time of about 6-7 years. It will not necessitate any new storage construction; only an intake and pumping by pipeline to the Spruce Run-Round Valley System. This project would require Federal, State, local and Delaware River Basin Commission approval. It is too late to implement this project in time to reduce the risk of shortage by 1980, although it can be operational shortly thereafter and restrictions can be used until then.

TABLE 7-3  
PROJECT IMPLEMENTATION POTENTIAL — NYMA

Demand management or restrictions programs would have to be implemented entirely by local government.

*Spruce Run-Round Valley* is the first project on all Branches. This project consists of the construction of a pipeline, reservoir outlet pipe and facility to make better use of available existing storage. It is currently under construction and will require about two years to become operational. The major issue was funding and institutional arrangements. It requires primarily State, local and utility decision making.

*Confluence Reservoir* is one of the first projects in Branches 1 and 2. It involves construction of the Confluence Reservoir on the Raritan River. This requires Federal, State, local and utility decisions. However, the lead-time is not as great as for

Project	present-1985	by year 2000	by year 2020
Round Valley	X	X	X
Confluence	X	X	X
Tocks Island Lake Project		X	X
Delaware Diversion	X	X	X
Tocks Island Lake Project Exchange		X	X
Two Bridges		X	X
South Jersey Groundwater	X	X	X
Hudson Ramapo Diversion	X	X	X
Hudson River High Flow Diversion (1)	X	X	X
Hudson River High Flow Diversion (2)		X	X
Trap Falls	X	X	X
Housatonic River Development (1)	X	X	X
Housatonic River Development (2)		X	X
Connecticut	X	X	X
Long Island Exchange	X	X	(3)
Total Resource		X	X
Metering — Project may be implemented in earlier time frames but effect will not be realized until year 2020.			

- (1) Initial stage.
- (2) Later stages.
- (3) This project will not operate beyond year 2020.

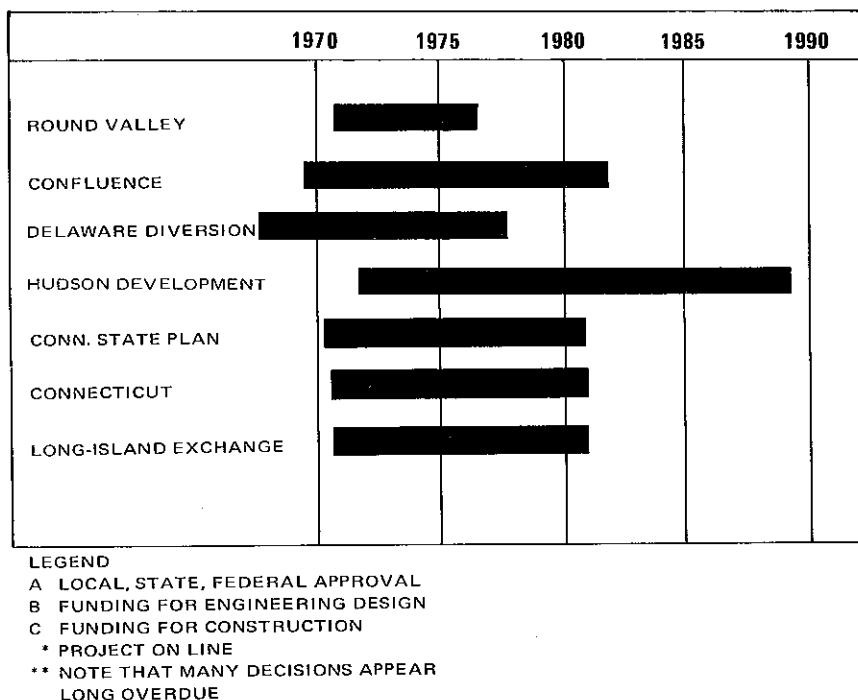


FIGURE 7-2. DECISION TIMING FOR INITIAL PROJECTS\*\*--NYMA

*Hudson River High Flow Diversion* is one of the first projects on Branches 1, 3 and 5. Required lead time depends upon the solution of complex institutional problems. These problems will arise in any attempt to utilize the Hudson River for water supply whether for New York, New Jersey or both. However, part of the initial phase of this project could be operational by the early 1980's if it is feasible to utilize a connection from West Park to Shaft 4 of New York City's Delaware Aqueduct as a first step. If this proves unfeasible, the additional lead time reflected in Figure 7-2 will be required. Implementation will require Federal, State and local decisions and agreements.

*The Connecticut State Plan* is the preferred plan for development by the State of Connecticut. It is one of the

first projects on Branches 3, 4 and 5. This plan involves groundwater development and several smaller reservoir developments. It is estimated that in order to implement the first series of projects in the Connecticut State Plan, it will require about 8 to 10 years of lead time. As in the case of the Hudson Gravity Aqueduct plan, the decision making will primarily be with State, local and utility groups. It is too late to make decisions to implement this project in time to meet 1980 needs although the initial projects could be operational shortly thereafter.

*Connecticut River* project is a diversion of the Connecticut River. It is one of the first projects on Branch 3. This diversion could be operational within an 8 to 10 year period. The project would require Federal, State, local and utility agreement before construction

could begin. There are several difficulties inherent in this project, including the fact that there is no available storage in the area, and that the use of the Connecticut River as a water supply source is contrary to State policy. It is too late to make decisions to implement this project in time to acceptably reduce the risk of shortage by 1980, although it could be operational shortly thereafter.

*Long Island Exchange* is a two-way exchange of water between Long Island and New York City. This project involves the construction of transmission facilities from Suffolk to New York City and back. The two-way exchange would require Federal, State and local decision for implementation to occur. It is estimated that the lead time for construction of the project is 9 to 10 years. Again a majority of the time would go to securing the necessary agreements and funding. Although it cannot be operational in time to acceptably reduce the risk of shortage by 1980 it can be operational shortly thereafter.

#### PLANNING ASSUMPTIONS

The following assumptions were made to formulate the alternative programs shown on the Decision Tree:

1. Local supplies would be developed to the level indicated in Table 7-2.
2. Remaining deficits would be supplied by regional programs.
3. Demand reduction was not assumed through use restrictions in the absence of specific locally adopted means to implement such restrictions.
4. Industrial water use was assumed to decrease per unit of industrial output to one-half the 1970 level

by 2020 because of improved recirculation rates.

Project physical characteristics (surface area, drawdown, etc.) and services (water supply, flood control, recreation, etc.) were related to economic, social, environmental and institutional impacts at both the local and regional levels. Assumptions were made regarding the importance of local project impacts to the region as a whole, to determine how each of these impacts affected the various desired regional objectives selected for the regional programs on the Decision Tree to best achieve those particular mixed objectives, as well as to meet the water supply needs of the region. Reports presenting details of this process are

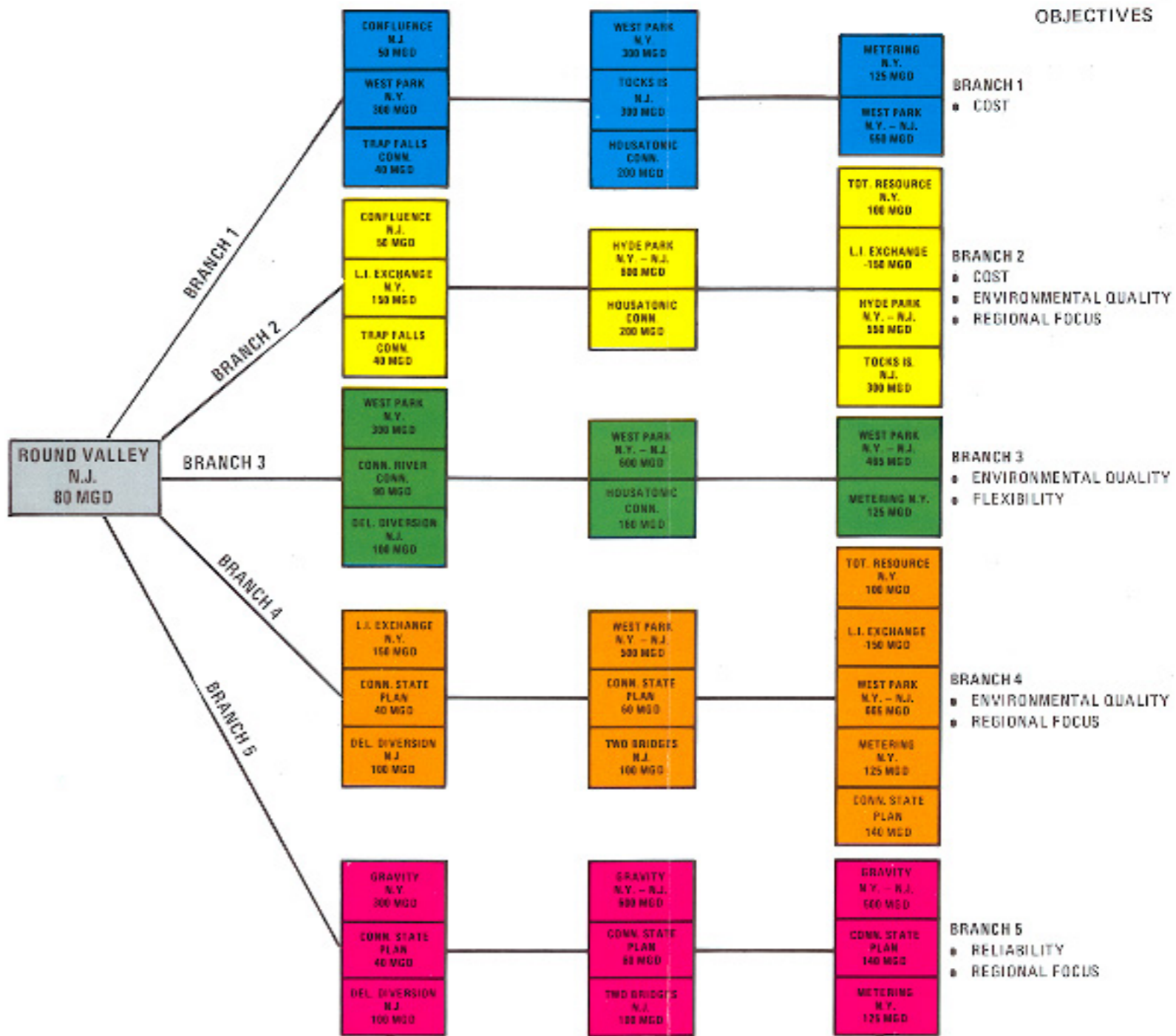
described in the Annotated Bibliography.

#### **COSTS AND CASH FLOW**

Local expenditure and cost data have been developed and are displayed for decision tree branches 1 through 5. These data demonstrate the financial sensitivity of program and user costs to local and extra local funding source assumptions. Comparison of estimated annual local expenditures through 2020 for both amortized capital construction costs and operation, maintenance and repair costs shows it to be less expensive to use extra local funding during the 50 year period (1970-2020) of analysis. This analysis was based upon the assumption that

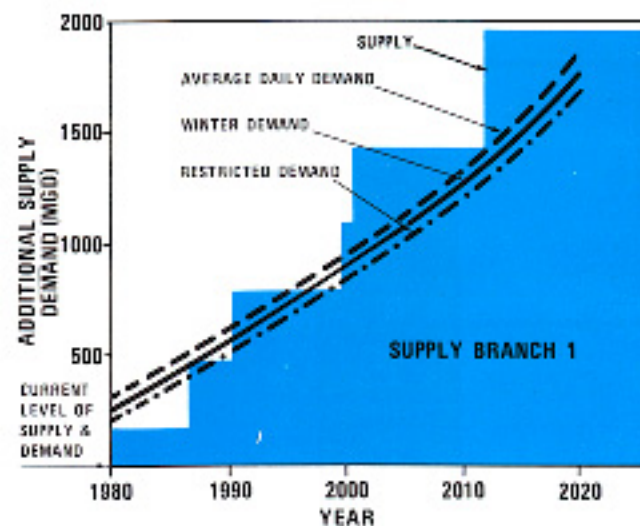
the 1958 Water Supply Act may be applied to obtain extra local funding. It includes a lower interest rate and a longer pay-back period, resulting in smaller annual payments, as well as an initial period of up to ten years during which no debt service payments are made and no interest is accrued. However, since in all cases local expenditures extend beyond 2020, total program expenditures are slightly greater, less than 1%, with extra local funding. Estimated cost per mgd of safe yield for 1980, 2000 and 2020 is higher for local funding because it has been calculated on the basis of a 10% reserve on debt service which is typically required by investment bankers on municipally funded projects.

FIGURE 7-3 DECISION TREE – NYMA PROJECTS

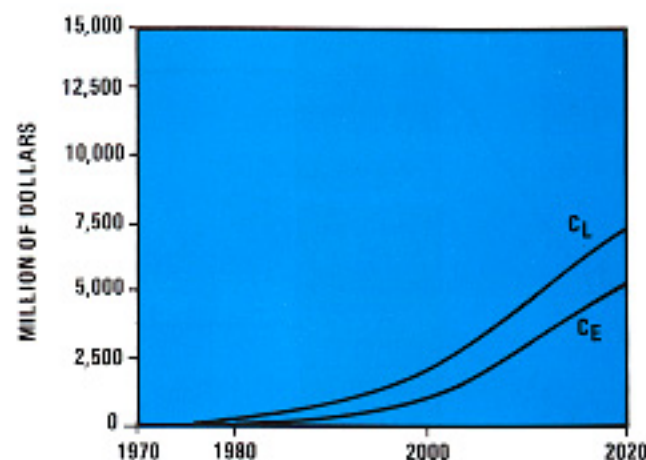


BRANCH	THROUGH 1988 ADDITIONAL DEMAND (MGD): 310			THROUGH 1986 ADDITIONAL DEMAND (MGD): 553			THROUGH 2028 ADDITIONAL DEMAND (MGD): 1918		
	ADDITIONAL SUPPLY MGD	LOCAL CASH FLOW (MILLIONS)		ADDITIONAL SUPPLY MGD	LOCAL CASH FLOW (MILLIONS)		ADDITIONAL SUPPLY MGD	LOCAL CASH FLOW (MILLIONS)	
		LOCAL FUNDING	EXTRA LOCAL FUNDING		LOCAL FUNDING	EXTRA LOCAL FUNDING		LOCAL FUNDING	EXTRA LOCAL FUNDING
1	430	196.3	15.7	1218	2485.0	1282.0	1645	3690.0	890.5
2	320	151.8	48.8	1128	3478.4	1659.7	1623	3270.0	8140.5
3	620	428.7	28.5	1338	2865.2	2655.3	1623	7084.4	5012.8
4	370	190.0	58.8	1308	3650.1	2346.7	1613	3337.0	8908.1
5	520	1892.8	27.7	1258	2810.2	2672.2	2043	12831.1	8958.7

ADDITIONAL SUPPLY DEMAND VS. TIME  
BRANCH 1

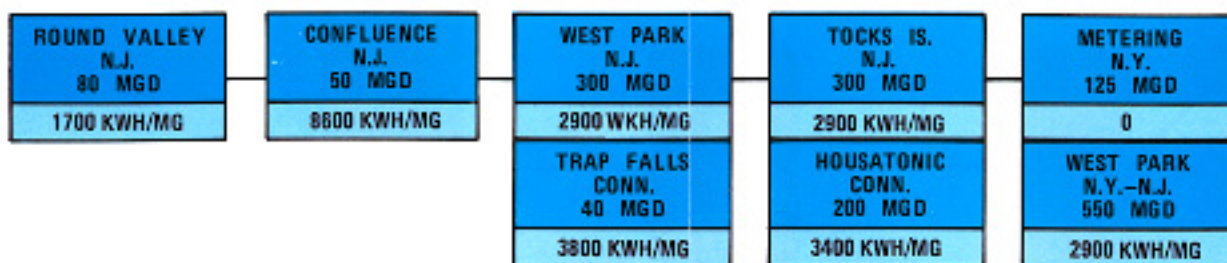


CUMULATIVE EXPENDITURES FOR BRANCH 1



$C_L$  - Local expenditures under local funding assumption  
 $C_E$  - Local expenditures under extra local funding assumption  
 Curves are approximate in shape due to scale of graph

DECISION TREE - BRANCH 1

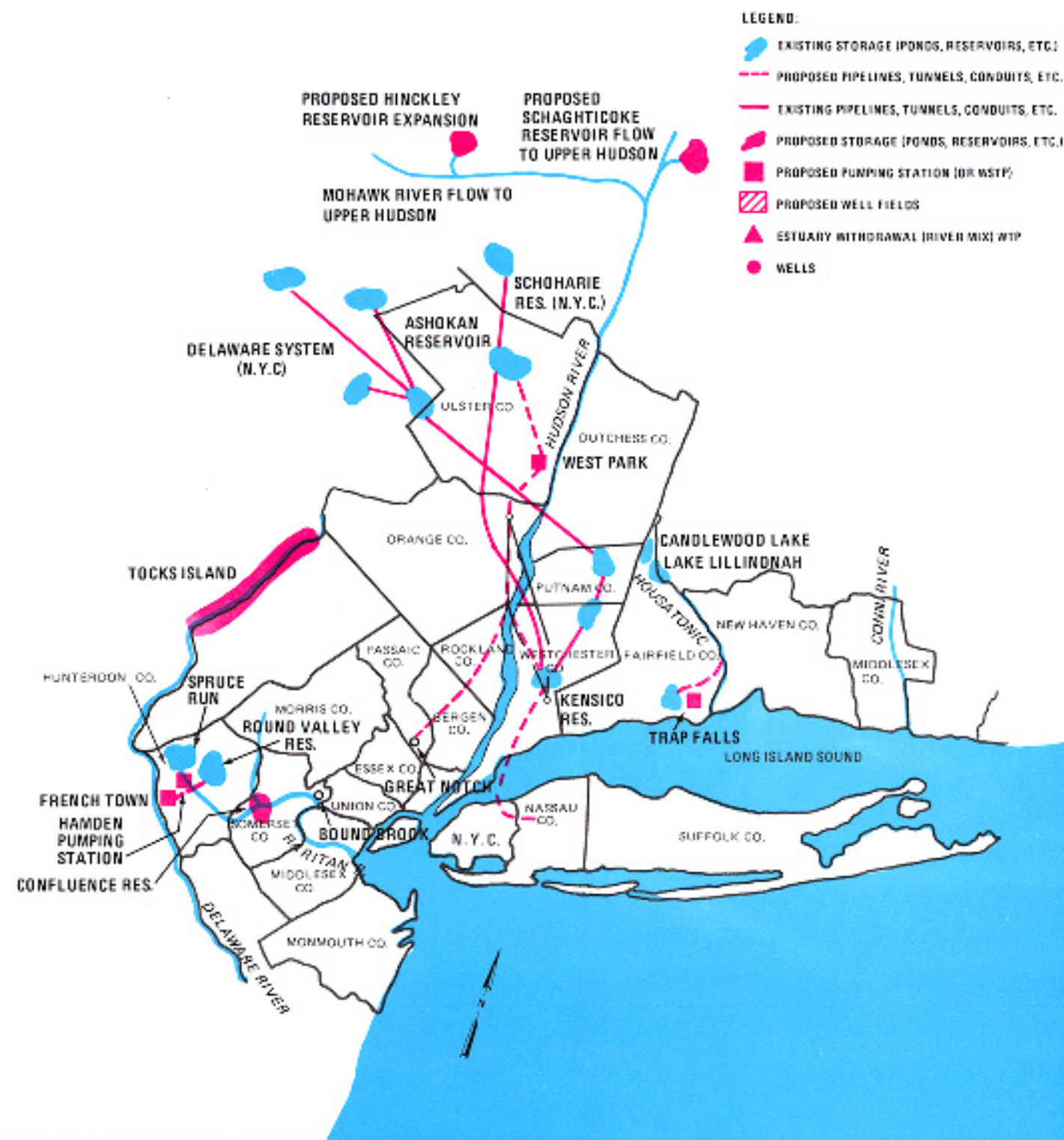


YEAR	1980	2000	2020
ADDITIONAL DEMAND (MGD)	310	950	1910
ADDITIONAL SUPPLY (MGD)	470	1270	1945
ENERGY REQUIREMENTS* KWH/MG	3400	3200	2900

\*AVERAGE

## BRANCH 1

• COST



**BRANCH NUMBER ONE** — A program designed for the least cost objective as well as water supply.

This branch of the decision tree reflects the desire of local interests to meet water needs at the least possible monetary cost to the region and the Nation. Projects were chosen for the first branch to meet the demand for water with the sole additional objective of least financial cost based on least annual cost per million gallons, disregarding all other considerations.

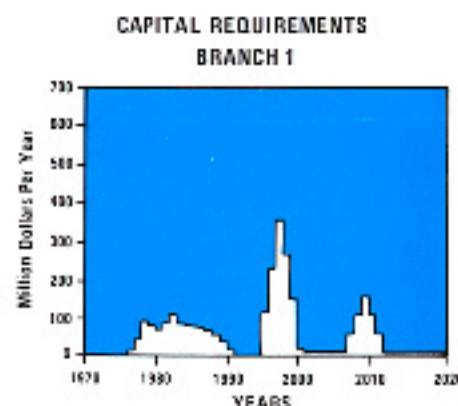
#### Program Description

1980 — Spruce Run-Round Valley would provide New Jersey with 80 mgd at a cost with local funding of \$198 per million gallons (mg). Confluence Reservoir would come on line with 50 mgd for New Jersey at a cost of \$506 per mg. High flow skimming from

the Hudson at West Park would provide New York with 300 mgd at a cost of \$492 per mg. Diversion of the Housatonic to Trap Falls Reservoir would provide Connecticut with 40 mgd at a cost of \$254 per mg.

2000 — Tocks Island Lake Project would provide New Jersey with 300 mgd at a cost of \$304 per mg. Connecticut would get 200 mgd, at a cost of \$163 per mg, from reregulation of Housatonic power reservoirs. This project will meet the Connecticut study area needs through 2020. New York's needs for this time period would be met by a total diversion of 600 mgd from the Hudson at West Park at a cost of \$586 per mg.

2020 — Metering of water use in New York City would provide a demand reduction of about 125 mgd at a cost of \$292 per mg. Further development of the West Park project would add 500 mgd for New Jersey and New York at a cost of \$376 per mg.



**PROJECT DATA FOR BRANCH 1\*\***

PROJECT	ULTIMATE SAFE YD. MGD	CAPITAL COST* \$ MILLIONS	ANNUAL* OM&R \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$ MILLIONS)					
					THROUGH 1980		THROUGH 2000		THROUGH 2020	
					LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
ROUND VALLEY	80	29.01	3.75	5,632	13.9	5.2	129.6	168.8	224.9	212.7
CONFLUENCE	50	68.67	3.17	17,804	27.5	7.5	212.2	166.6	342.4	305.8
TOCKS IS.	300	304.08	12.26	38,181	0	0	480.5	273.3	1104.6	619.8
HUDSON RIVER	1150	2056.70	64.66	139,280	112.9	0	1547.7	660.3	4593.5	3104.3
METERING	125	144.0	3.23	0	0	0	0	0	266.6	207.2
TRAP FALLS	40	34.66	1.30	64,16	11.0	3.0	85.5	63.3	138.1	123.5
HOUSATONIC	200	110.73	4.18	28,348	0	0	31.1	0	209.9	193.3
<b>TOTAL</b>	<b>1945</b>	<b>2765.65</b>	<b>72.35</b>	<b>233,761</b>	<b>165.3</b>	<b>15.7</b>	<b>2486.8</b>	<b>1262.4</b>	<b>6940.0</b>	<b>4866.6</b>

\*AT COMPLETION

\*\*ALL FIGURES IN 1974 DOLLARS

#### Program Rationale

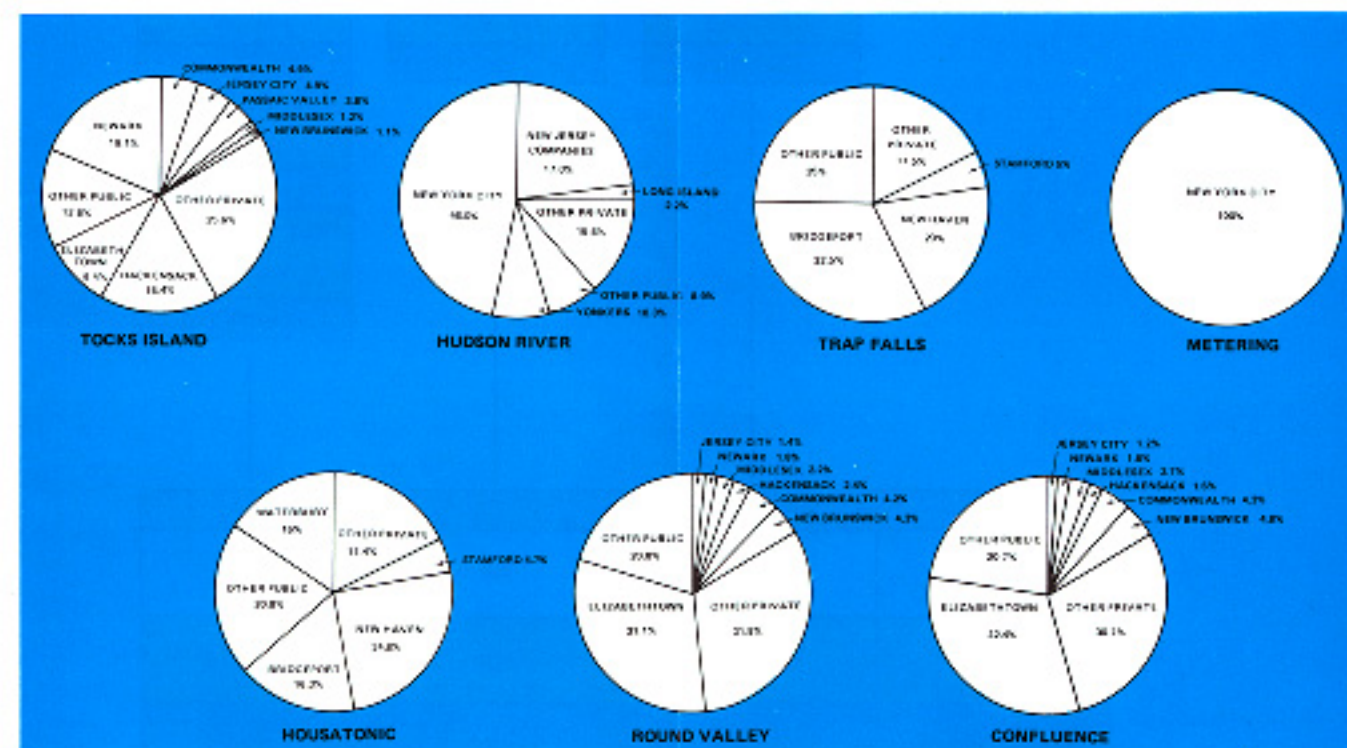
In general the least cost objective can be evaluated by a comparison of annual costs. Annual costs include interest or amortization on the capital cost, and the operating expenses of a project. These operating expenses are for personnel, power, chemicals, replacements, maintenance, taxes and other payments necessary to keep a

project in operating condition and delivering water, and to retire the debts incurred in its construction. Given this figure, the cost per mg is determined by dividing annual costs by annual production at safe yield capacity.

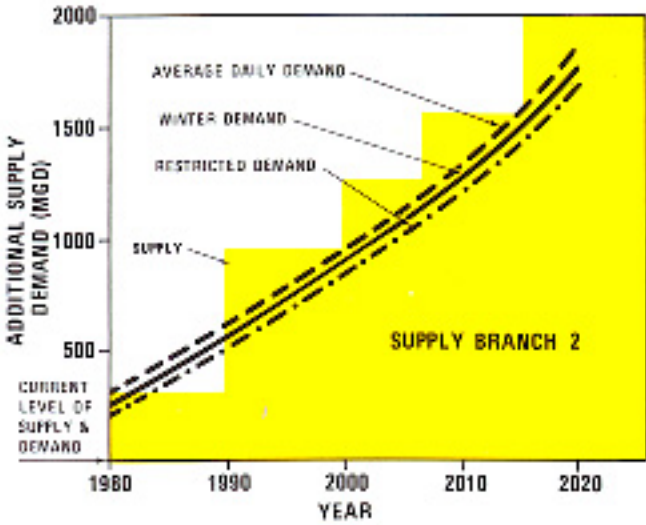
Capital costs are the lowest for any Branch except Branch 3. Annual

operation, maintenance and replacement costs are estimated to be the lowest, and the local expenditures reflecting annual costs under both local and extra local funding assumptions are the lowest.

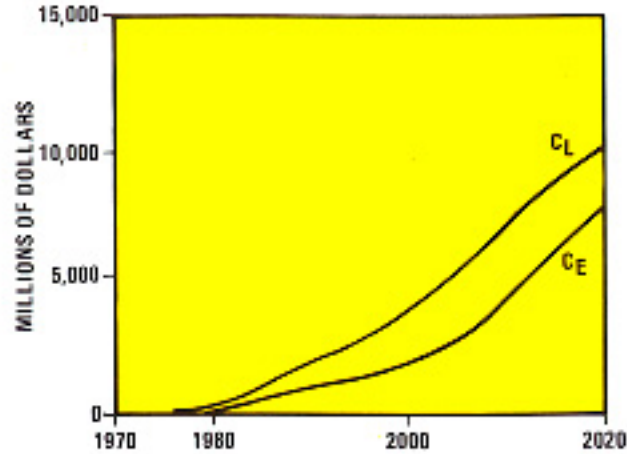
**DISTRIBUTION OF EXPENDITURES FOR BRANCH 1**



ADDITIONAL SUPPLY DEMAND VS. TIME  
BRANCH 2

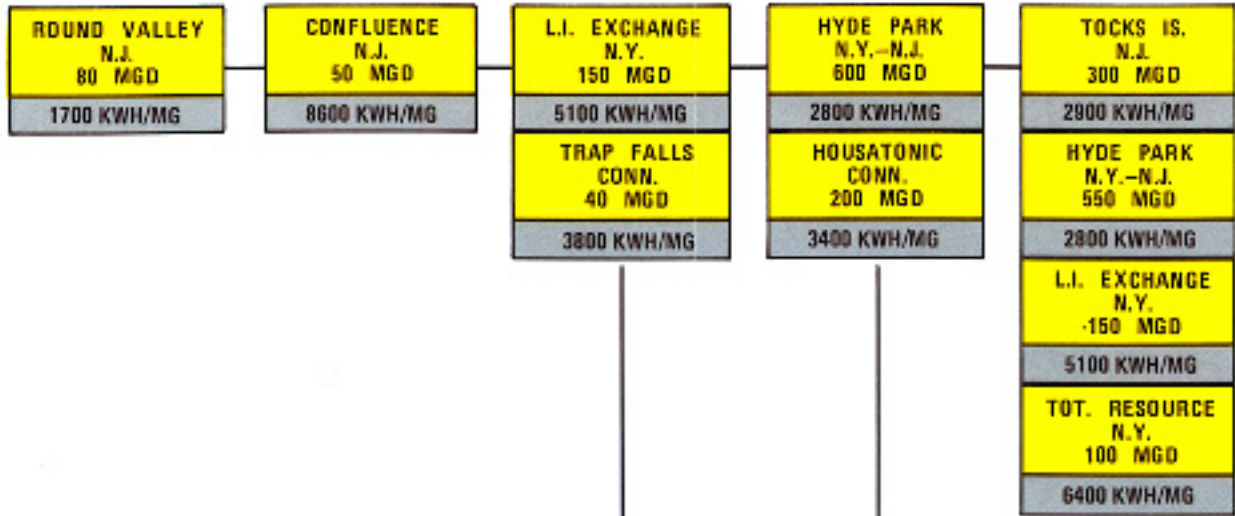


CUMULATIVE EXPENDITURES FOR BRANCH 2



CL - Local expenditures under local funding assumption  
CE - Local expenditures under extra local funding assumption  
Curves are approximate in shape due to scale of graph

DECISION TREE - BRANCH 2



YEAR	1980	2000	2020
ADDITIONAL DEMAND (MGD)	310	950	1910
ADDITIONAL SUPPLY (MGD)	320	1120	1920
ENERGY REQUIREMENTS* KWH/MG	4700	3400	3200

\*AVERAGE

BRANCH 2

- REGIONAL FOCUS
- ENVIRONMENTAL QUALITY



BRANCH NUMBER TWO — A program designed to satisfy the objectives of cost, environmental quality, and regional focus, as well as providing water supply.

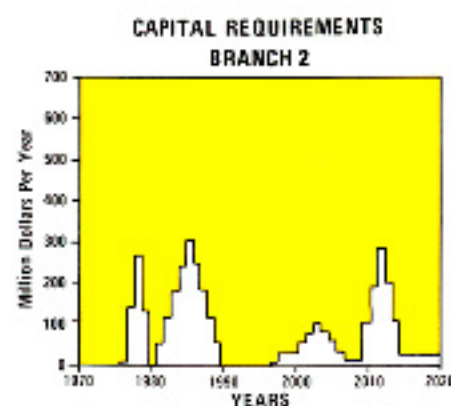
Branch 2 is designed for a complicated set of additional objectives. The mix reflects the desire of local officials to meet the demand for water at reasonable monetary and non-monetary costs, using projects having a positive impact on the environment of both the source and user areas, and making the most geographically efficient use of resources. The practical attainment of this mix of regional objectives is difficult and involves many tradeoffs.

#### Program Description

1980 — As with the previous branch, this branch begins with the use of Spruce Run-Round Valley

in New Jersey providing 80 mgd. This project would be followed by Confluence Reservoir providing New Jersey with an additional 50 mgd. For the New York area, the Long Island Exchange Project would go on line with up to 150 mgd. In this project Long Island would be partially supplied by the New York City system during non-drought years. However, during dry periods, Long Island groundwater would be furnished to Nassau County and New York City. For Connecticut, a diversion from the Housatonic to Trap Falls would provide 40 mgd.

through the year 2020. A regional project, the Hudson diversion at Hyde Park would supply the New Jersey-New York City Metropolitan Area with 800 mgd.



#### PROJECT DATA FOR BRANCH 2\*\*

PROJECT	ULTIMATE SAFE YD. MGD	CAPITAL COST* \$ MILLIONS	ANNUAL* OM&R \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$ MILLIONS)					
					THROUGH 1980		THROUGH 2000		THROUGH 2020	
					LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
ROUND VALLEY	80	29.01	3.75	5,832	13.0	5.2	129.6	108.9	224.9	212.7
CONFLUENCE	50	85.57	3.17	17,904	27.6	7.5	212.2	156.6	342.4	305.8
HUDSON RIVER	1150	2056.74	44.46	134,802	0	0	2163.8	991.9	4709.2	3132.5
HOUSATONIC	200	110.73	4.18	28,348	0	0	31.1	0	269.9	193.3
TRAP FALLS	40	34.56	1.30	6,416	11.0	3.0	85.5	63.3	138.1	123.5
TOCKS IS.	300	304.08	12.26	36,181	0	0	21.1	0	613.7	382.8
L.I. EXCHANGE	150	325.50	14.16	32,078	105.4	30.3	845.1	636.0	1379.3	1241.8
TOTAL L.I. RESOURCES MGT.	100	357.30	10.02	26,856	0	0	0	0	701.4	554.4
TOTAL	1920***	3304.49	93.3	287,917	157.8	48.8	3478.4	1956.7	8378.9	6146.8

\*AT COMPLETION

\*\* ALL FIGURES IN 1974 DOLLARS

\*\*\* L.I. EXCHANGE OFF LINE BY 2020

2020 — The release of water from the Tocks Island Lake Project for diversion at Frenchtown would provide 300 mgd for New Jersey. Further development of the Hudson diversion at Hyde Park would provide 550 mgd for New York and New Jersey. The Long Island Exchange project would be phased out as a regional project by this time, as Long Island's local demands grow too large to permit the export of its water elsewhere. However, the possibility of supplementing Long Island's water through a connection to the Hudson diversion via the New York City system would exist. Total Resource Management on Long Island, which may yield up to 100 mgd, may

minimize the need to rely on water from the New York City system.

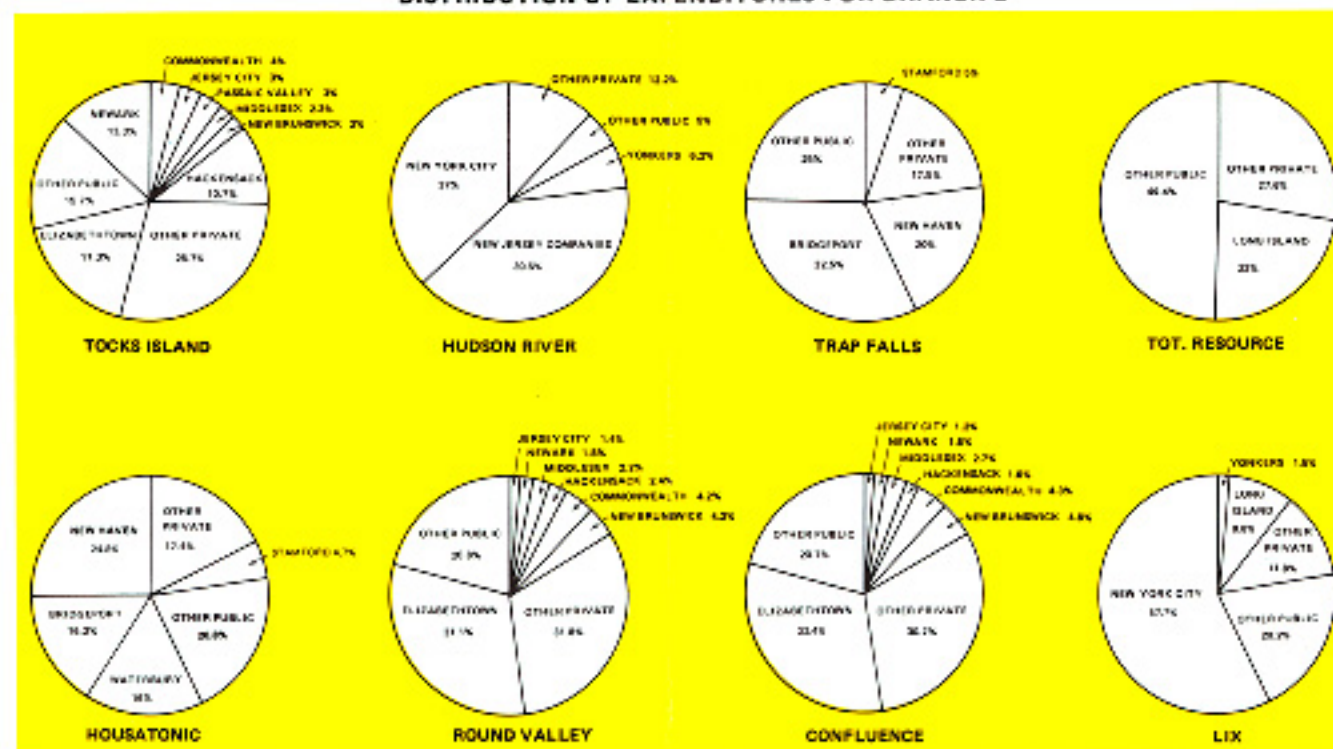
#### Program Rationale

The projects in Branch 2 minimize political, institutional and fiscal impacts minimizing interstate transfers of water in the near-term, yet providing for the efficient use of regional sources in the long-term. This branch also minimizes environmental impacts and costs of construction and operation through the use of existing reservoirs.

This branch relies initially on in-state sources. However, as the region continues its growth, it will be necessary for the relatively water scarce areas to cross state lines to get water by the year 2000. The Hudson River diversion supplement with the Hinck-

ley Reservoir expansion has been analyzed as bringing positive environmental and economic effects. This coupled with high-flow skimming on the Delaware, will effectively meet the demands of the area through 2000. In 2020, the potential development of the Hudson would continue with further use of the Hudson Diversion project, supplemented by upstream reservoirs.

#### DISTRIBUTION OF EXPENDITURES FOR BRANCH 2



\*AVERAGE

**BRANCH NUMBER THREE** — A program designed to satisfy the objectives of environmental quality and flexibility, as well as providing water supply.

The projects selected for Branch 3 meet the demand for water while complementing environmental quality and exhibiting flexibility to accommodate possible shifts in location or level of future water demands. Additional costs are incurred to obtain these qualities.

#### Program Description

**1980** — As with the two previous branches, the first project is the Spruce Run-Round Valley system providing 80 mgd for New Jersey. Another 100 mgd would be provided to New Jersey through the Delaware River diversion to Round

Valley during periods of high-flow. New York would meet its water demands with Hudson high-flow skimming at West Park. This project in its initial stages would supply the City with 300 mgd. Connecticut would meet its demand for an additional 90 mgd by a diversion of the Connecticut River at Middletown. This project would require upstream storage to meet minimum flow requirements.

**2000** — Further development, including a link to Ashokan Reservoir from the Hudson at West Park, would supply both New Jersey and New York with an additional 600 mgd. It would include expansion of the Hinckley Reservoir and transfer of water to New Jersey.

Connecticut's demand for an additional 160 mgd would be met by the reregulation of the Housatonic River power reservoirs.

**2020** — The final stages of the Hudson diversion at West Park will

supply New York and New Jersey with an additional 485 mgd. New York City's demand for another 125 mgd would be eliminated by the completion of universal metering in the city.

#### Program Rationale

The projects in Branch 3 have two distinct characteristics. They are flexible with regard to yield levels and do not require a large irreversible investment decision early in the planning period. Evaluation has shown they either sustain or improve the environment of the area in which they would be located as well as the region as a whole.

The Spruce Run-Round Valley project requires only a five mile long pipeline, and the other three projects require diversion of the Connecticut River and

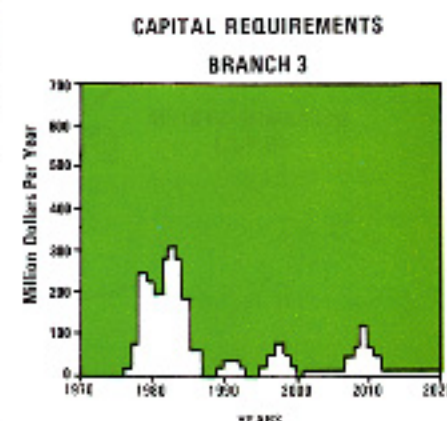
high flow skimming of the Hudson and Delaware Rivers.

For the year 2000, an expansion of Hinckley Reservoir and the Hudson Diversion project either enhance or minimize environmental impact while also being flexible. The reregulation of existing power reservoirs in Connecticut also meets the additional objectives.

Expansion of Hinckley will eliminate the current severe drawdowns providing improved recreational opportunities in that area, improving the environment. It will also improve the local economy by providing jobs. The reregulation of the existing power reservoirs in Connecticut has some environmental drawbacks, particularly the adverse effect on some recreational activity. It does, however, avoid new construction while meeting the flexibility objective.

The last two projects for the 2020 demand again minimize the development of new projects and transmission facilities. The metering project may reduce demands and the extension of the Hudson River project by additional upstream impoundment will provide the additional water demand. Because of the nature of the projects, they will not have major adverse impacts on the environment and will provide the flexibility to develop only to the level necessary to meet demands.

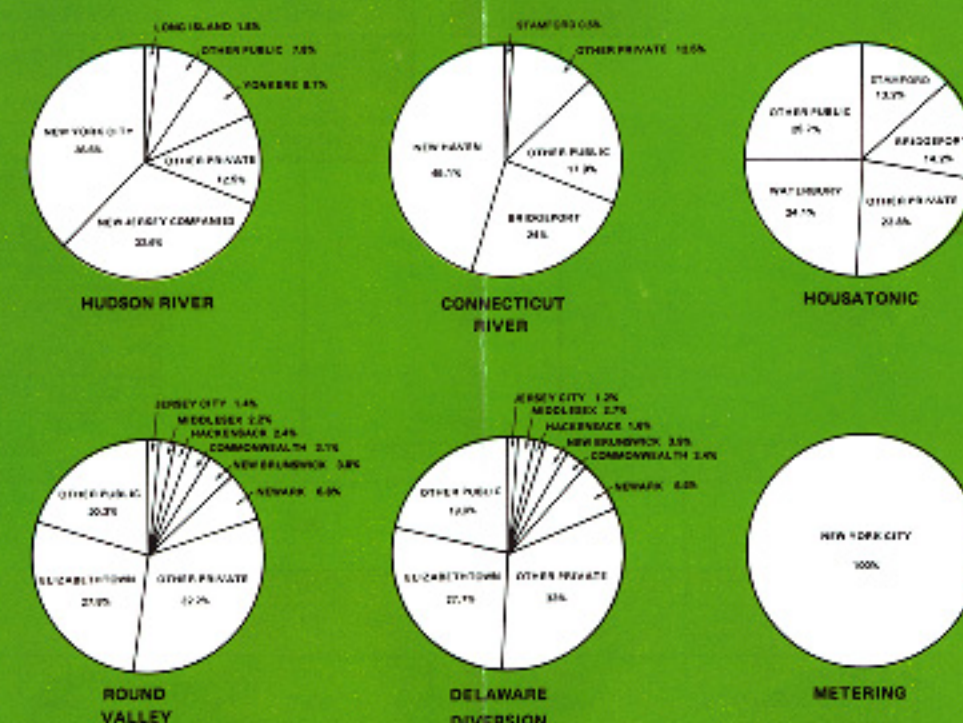
**PROJECT DATA FOR BRANCH 3\*\***



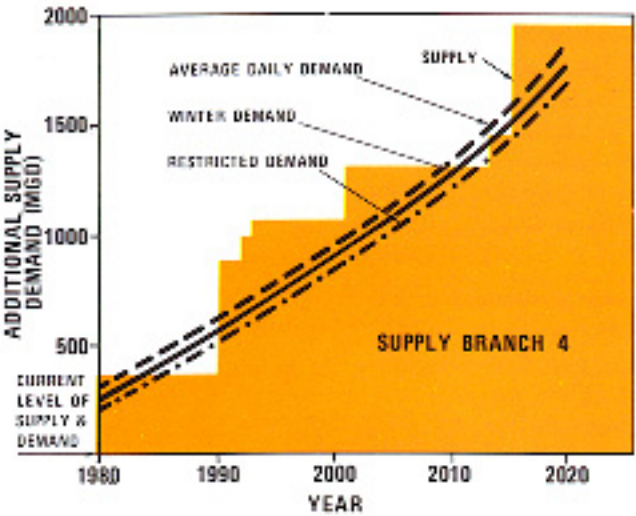
PROJECT	ULTIMATE SAFE YD. MGD	CAPITAL COST* \$ MILLIONS	ANNUAL* OM&R \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$ MILLIONS)					
					THROUGH 1990		THROUGH 2000		THROUGH 2020	
					LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
ROUND VALLEY	80	29.01	3.75	6,832	13.9	5.2	129.6	108.9	224.9	212.7
DEL. DIVERSION	100	165.93	6.35	26,707	52.9	14.6	412.6	306.0	667.5	597.4
HUDSON RIVER	1395	2193.7	52.75	165,319	336.3	0	2920.1	1360.7	5737.0	4128.3
CONN. RIVER	90	116.50	3.89	16,263	36.6	9.7	277.7	202.9	446.4	395.1
HOUSATONIC	160	119.73	4.18	22,676	0	0	118.2	77.3	343.8	279.7
METERING	125	144.00	3.23	0	0	0	0	0	268.6	207.2
<b>TOTAL</b>	<b>1920</b>	<b>2758.87</b>	<b>74.15</b>	<b>238,699</b>	<b>439.7</b>	<b>29.5</b>	<b>3858.2</b>	<b>2055.8</b>	<b>7684.4</b>	<b>5812.4</b>

\*AT COMPLETION  
\*\*ALL FIGURES IN 1974 DOLLARS

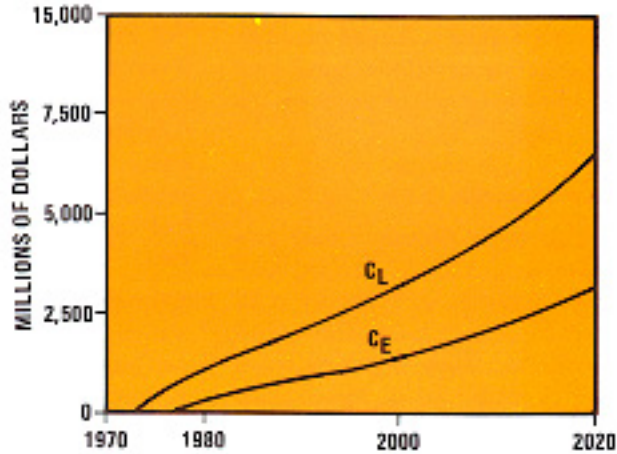
**DISTRIBUTION OF EXPENDITURES FOR BRANCH 3**



ADDITIONAL SUPPLY DEMAND VS. TIME  
BRANCH 4

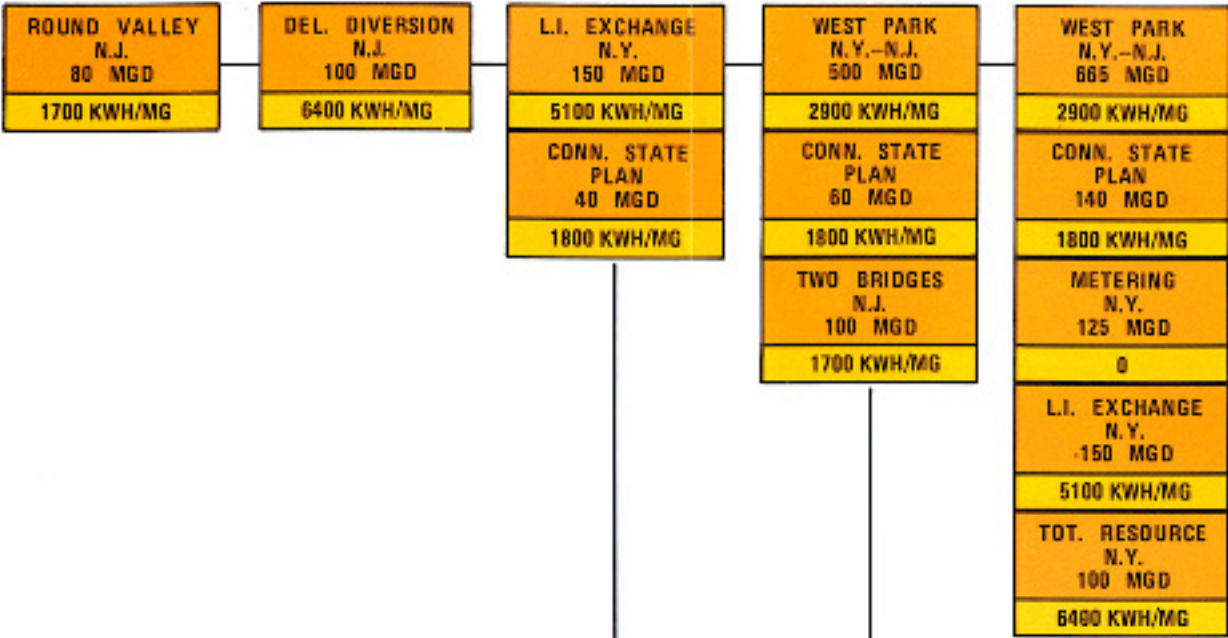


CUMULATIVE EXPENDITURES FOR BRANCH 4



CL – Local expenditures under local funding assumption  
CE – Local expenditures under extra local funding assumption  
Curves are approximate in shape due to scale of graph

DECISION TREE – BRANCH 4

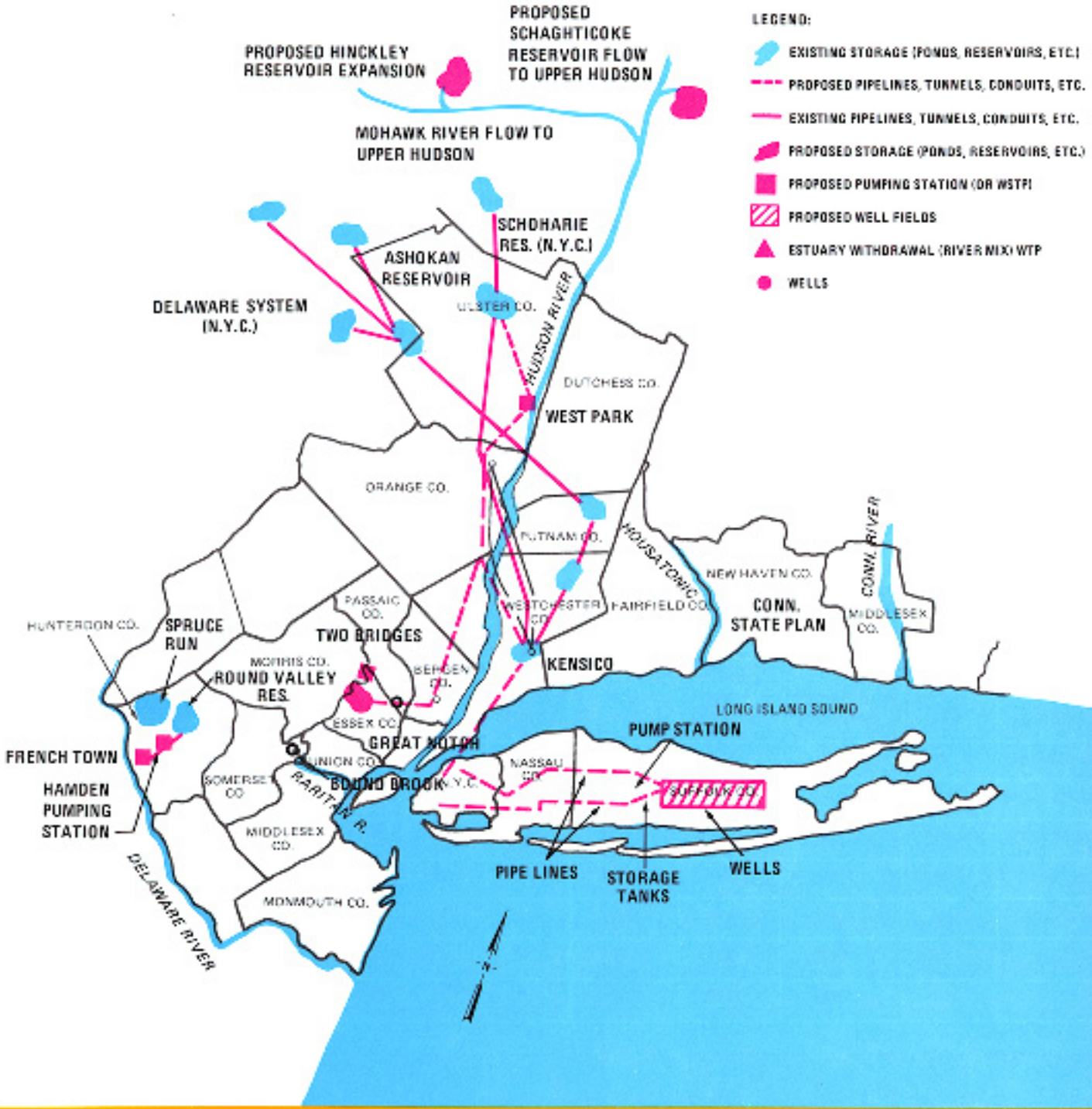


YEAR	1980	2000	2020
ADDITIONAL DEMAND (MGD)	310	950	1910
ADDITIONAL SUPPLY (MGD)	370	1030	1910
ENERGY REQUIREMENTS* KWH/MG	4400	3300	2800

\*AVERAGE

## BRANCH 4

- REGIONAL FOCUS
- ENVIRONMENTAL QUALITY



BRANCH NUMBER FOUR — A program designed to satisfy the objectives of environmental quality and regional focus, as well as providing water supply.

Branch 4 contains projects which make the most efficient use of water sources over a given geographic area while minimizing negative impacts on the environment. Smaller, local projects, which are environmentally less disruptive than large construction projects, are developed in a regionally efficient manner to meet near term needs. During later time frames, however, larger regional sources would have to be tapped, but less extensively due to Total Resource Management on Long Island and the metering of New York City.

#### Program Description

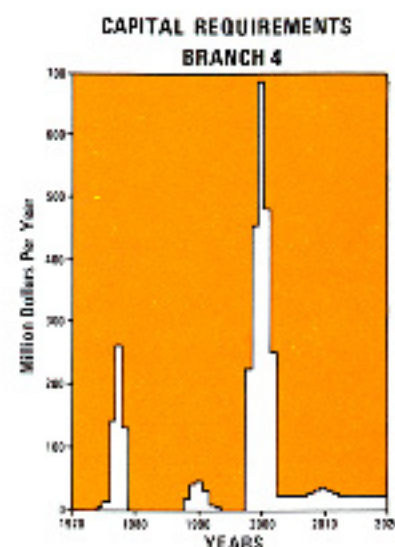
1980 —With the Spruce Run-Round Valley project supplying New

Jersey with 80 mgd, high flow skimming of the Delaware will provide an additional 100 mgd for the State. New York can add up to 150 mgd to its supply by implementing the Long Island Exchange Project. Connecticut will meet its additional demands through 2020 with its State Plan.

2000 — The Hudson Diversion at West Park coupled with the Hinckley Reservoir expansion will meet demands in New Jersey and New York with 500 mgd. New Jersey's demand for an additional 100 mgd would be met by development of the Two Bridges project in the Passaic River Basin.

2020 — Further development of the Hudson diversion at West Park would supply New York and

New Jersey with 665 mgd. The Long Island Exchange project, which had contributed up to 150 mgd, would no longer be available. Total Resource Management on Long Island would provide up to 100 mgd and metering in New York City would reduce demands by as much as 125 mgd.



PROJECT DATA FOR BRANCH 4\*\*

PROJECT	ULTIMATE SAFE YD. MGD	CAPITAL COST* \$ MILLIONS	ANNUAL* OM&R \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$ MILLIONS)					
					THROUGH 1980		THROUGH 2000		THROUGH 2020	
					LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
ROUND VALLEY	80	29.01	3.75	5,832	13.9	5.2	128.6	108.9	224.3	212.7
DEL. DIVERSION	100	185.93	6.35	26,707	52.9	14.6	412.8	306.0	667.5	587.4
L.I. EXCHANGE	150	325.5	14.16	32,078	105.4	30.3	845.1	636.0	1379.3	1241.8
CONN. STATE PLAN	240	124.29	17.61	18,430	23.3	7.9	274.7	221.8	678.5	602.1
HUDSON RIVER	1165	2056.7	44.68	141,097	0	0	2153.8	991.9	4709.2	3132.5
TWO BRIDGES	100	118.40	3.03	7,012	0	0	134.3	80.1	359.6	258.0
METERING	125	144.80	3.23	0	0	0	0	0	268.6	207.2
RESOURCE MGT.	100	357.3	10.02	26,856	0	0	0	0	701.4	554.4
TOTAL L.I. TOTAL	1910***	3321.13	102.83	257,812	195.5	58.0	3950.1	2344.7	6987.0	6806.1

\*AT COMPLETION

\*\*ALL FIGURES IN 1974 DOLLARS

\*\*\*L.I. EXCHANGE OFF LINE BY 2020

#### Program Rationale

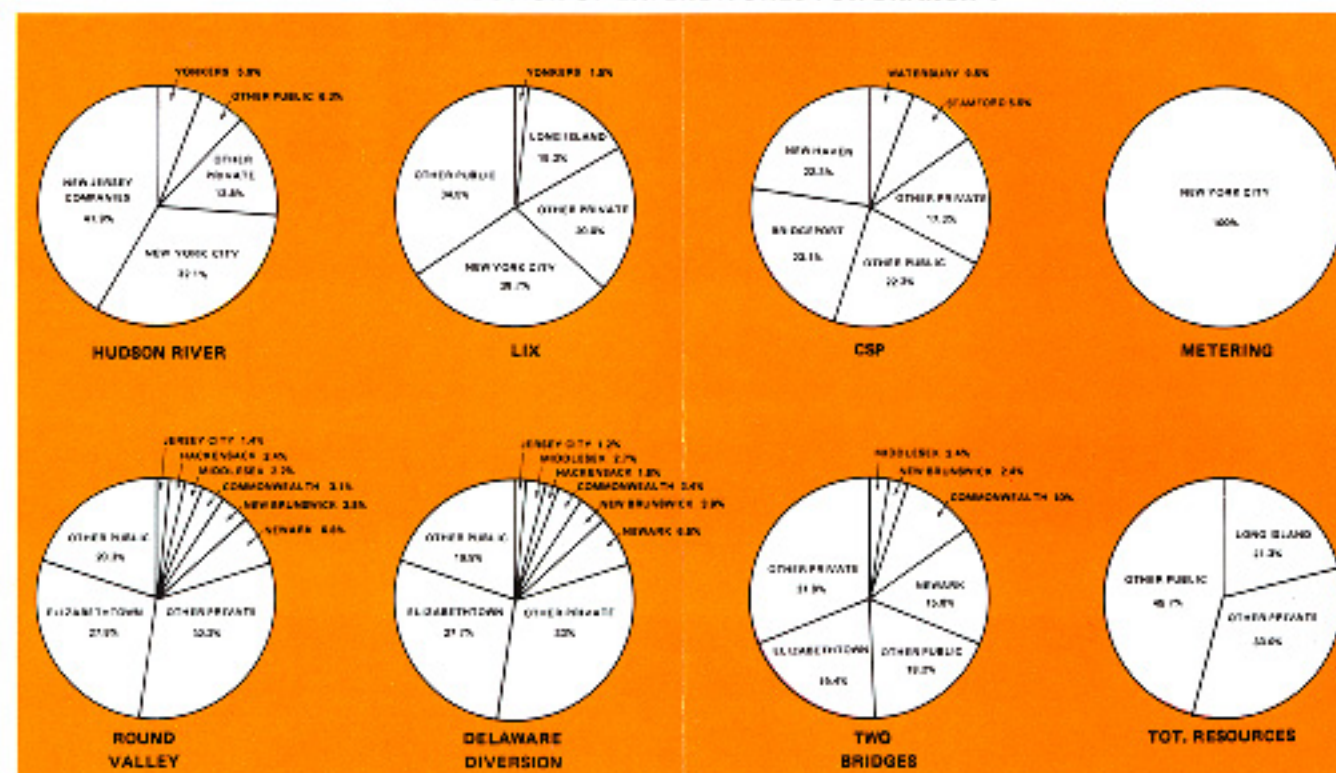
The environmental impacts of the projects and the different types of induced alterations in the economic, demographic and social characteristics of the region, involve fairly little disruption up to the year 2000 because they do not involve large construction projects. Rather they involve high flow skimming without reservoirs in both the Delaware and the Hudson and the

use of the Connecticut State Plan for Conservation and Development, a plan that reflects a strong concern for environmental quality.

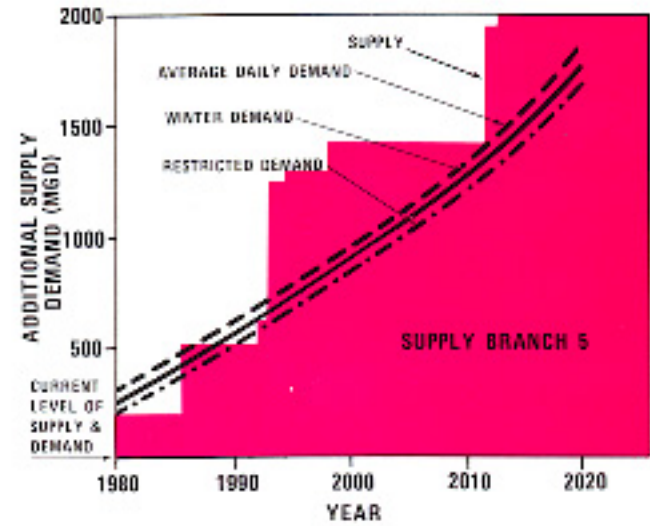
The early development of local sources postpones the need to negotiate for the interstate transfer of water. Existing institutional arrangements would have to be altered somewhat to provide for the interstate transfer of

water. However, interstate transfers become a necessity only after the year 2000 because New Jersey would be unable to meet its demands after that year without turning to the Hudson River for supplies. At that point, development to supplement the already existing high flow skimming project with an upstream impoundment may be needed to increase its yield.

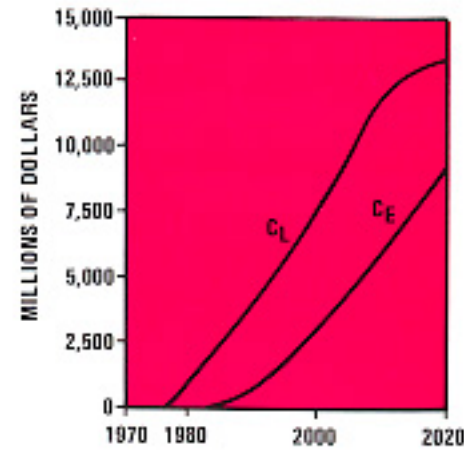
DISTRIBUTION OF EXPENDITURES FOR BRANCH 4



ADDITIONAL SUPPLY DEMAND VS. TIME  
BRANCH 5

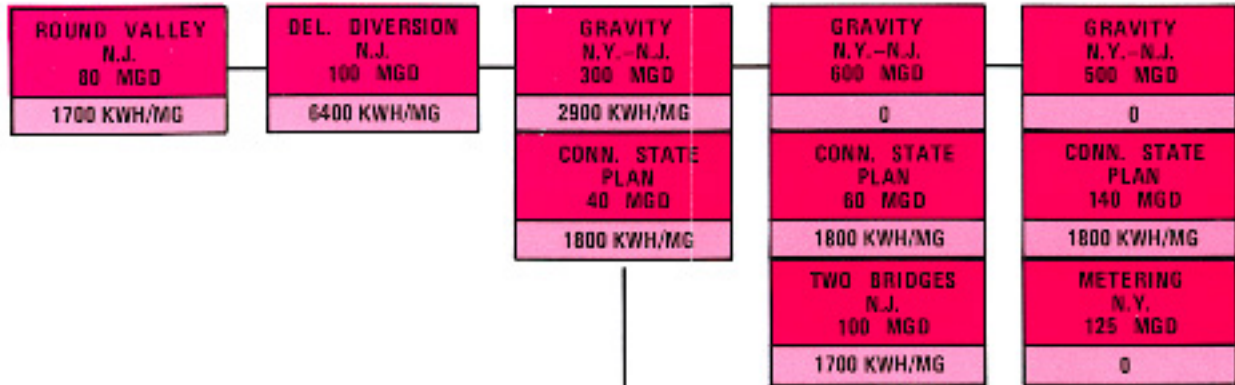


CUMULATIVE EXPENDITURES FOR BRANCH 5



CL — Local expenditures under local funding assumption  
CE — Local expenditures under extra local funding assumption  
Curves are approximate in shape due to scale of graph

DECISION TREE — BRANCH 5

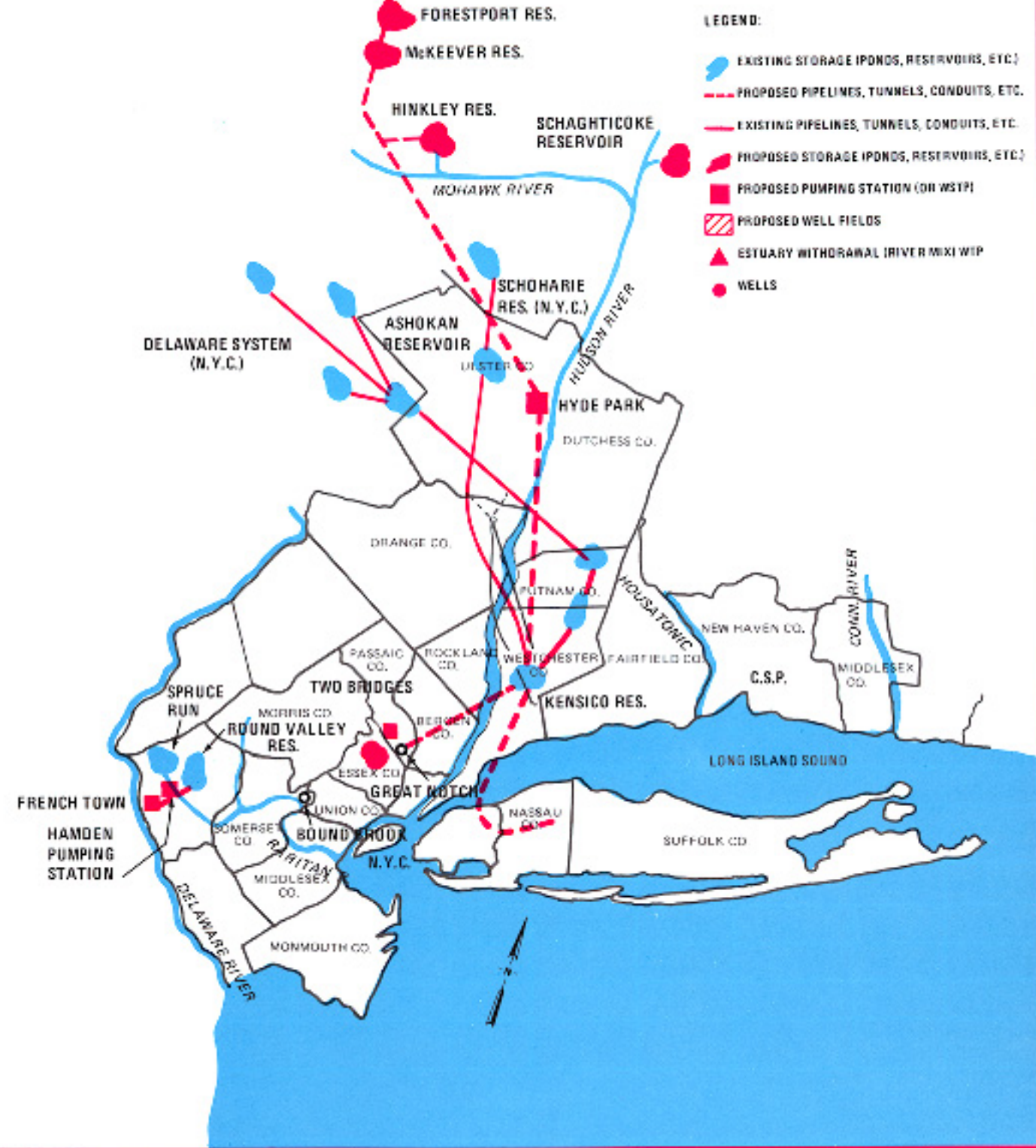


YEAR	1980	2000	2020
ADDITIONAL DEMAND (MGD)	310	950	1910
ADDITIONAL SUPPLY (MGD)	520	1280	2045
ENERGY REQUIREMENTS* KWH/MG	3300	1600	1100

\*AVERAGE

BRANCH 5

- RELIABILITY
- REGIONAL FOCUS



BRANCH NUMBER FIVE — A program designed to satisfy the objectives of regional focus and reliability, as well as providing water supply.

This branch favors regional focus and reliability of operation. To some extent, these additional objectives complement each other, but at the expense of failing to minimize costs and adverse environmental impacts.

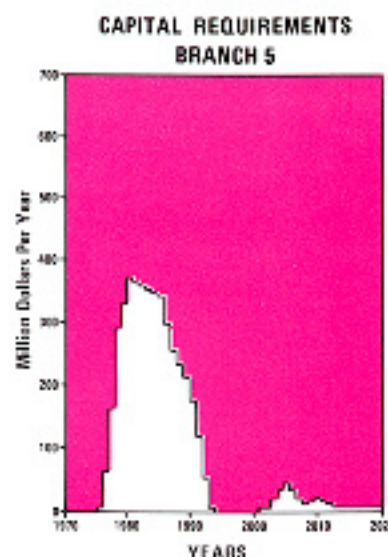
#### Program Description

1980 — In New Jersey the full utilization of the Spruce Run-Round Valley system will provide 80 mgd and high-flow skimming of the Delaware, will yield an additional 100 mgd. New York will begin major development of a gravity system for the upper Hudson River Basin.

This project will initially include high-flow skimming for 300 mgd at Hyde Park with a tunnel from Hyde Park to Kensico Reservoir, which is part of the present NYC water supply system. Connecticut will meet its additional demands through 2020 with its Connecticut State Plan.

2000 — Further development of the gravity system will continue in the upper Hudson with the expansion of Hinckley Reservoir and the development of the Forestport-McKeever sites. A tunnel linking Hyde Park via Ashokan Reservoir would provide for an additional 600 mgd, transported via gravity flow to the NYC system.

Some of this water would be utilized to meet the needs of northern New Jersey. New Jersey would gain an additional 100 mgd by development of Two Bridges Reservoir in the Passaic Basin.



PROJECT DATA FOR BRANCH 5\*\*

PROJECT	ULTIMATE SAFE YD. MGD	CAPITAL COST* \$ MILLIONS	ANNUAL* OM&R \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$ MILLIONS)					
					THROUGH 1980		THROUGH 2000		THROUGH 2020	
					LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
ROUND VALLEY	80	29.01	3.75	5,832	13.8	5.2	129.6	108.9	224.9	212.7
DEL. DIVERSION	100	105.93	6.35	26,707	52.9	14.6	412.6	306.0	667.5	597.4
GRAVITY	1400	4089.00	26.23	55,950	1005.7	0	6867.0	2355.4	10634.0	6819.3
CONN. STATE PLAN	240	124.29	17.61	18,430	23.3	7.0	274.7	221.8	676.5	602.1
TWO BRIDGES	100	118.40	3.03	7,012	0	0	134.3	80.1	359.6	258.0
METERING	125	144.00	3.23	0	0	0	0	0	266.6	207.2
TOTAL	2045	4670.63	69.20	113,731	1095.8	27.7	7918.2	3072.2	12831.1	8696.7

\*AT COMPLETION

\*\*ALL FIGURES IN 1974 DOLLARS

2020 — Further development of the Hudson gravity system calls for an additional reservoir to provide 500 mgd for New Jersey and New York. Metering of New York City would reduce demand by 125 mgd.

#### Program Rationale

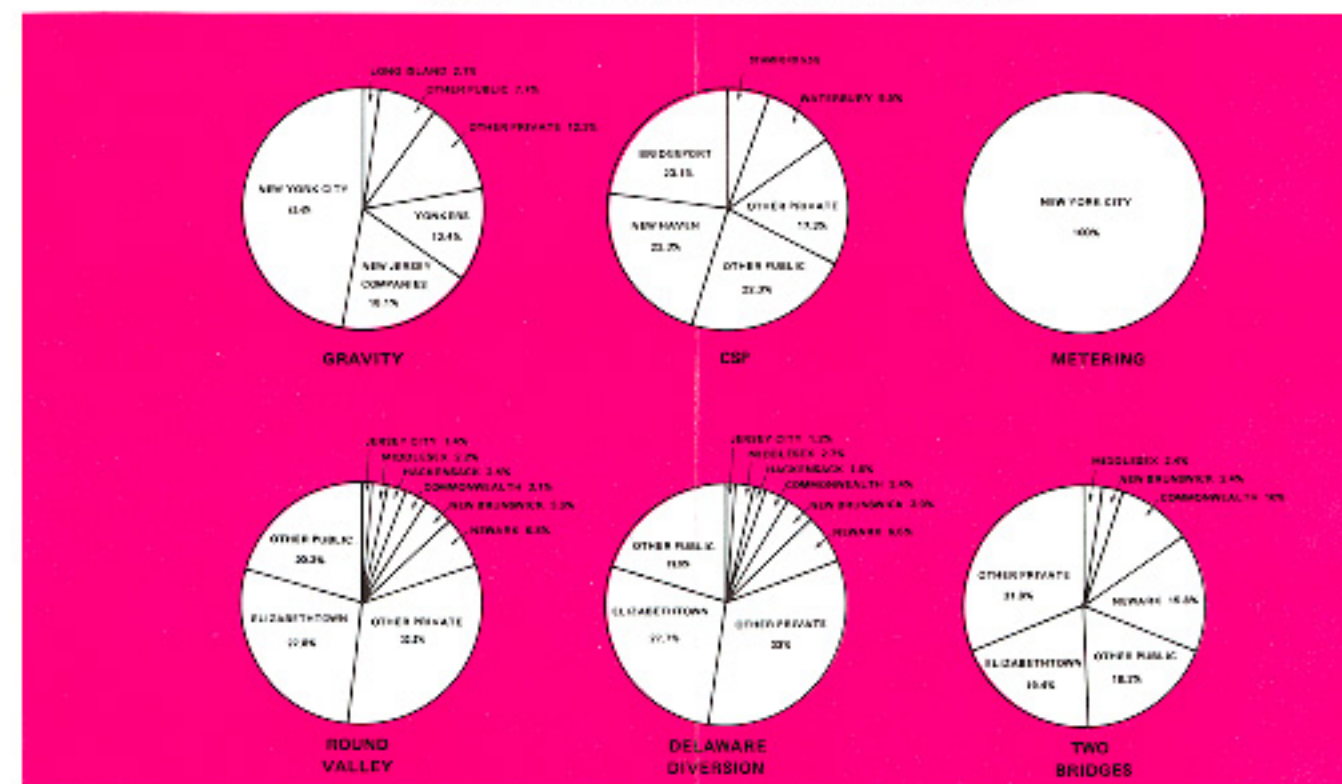
This branch includes elements of the proposed State Plans for New Jersey and Connecticut which emphasize regionally efficient water supply devel-

opment within state boundaries as far as possible. By the turn of the century, however, use of the Hudson by New Jersey becomes unavoidable.

System reliability is provided through conjunctive development of the Hudson by combining high-flow skimming with the direct tunnel from Hinckley Reservoir. This allows for the maximum hydrologic use of the Hudson Basin, and provides two independent paths for the transmission of water to

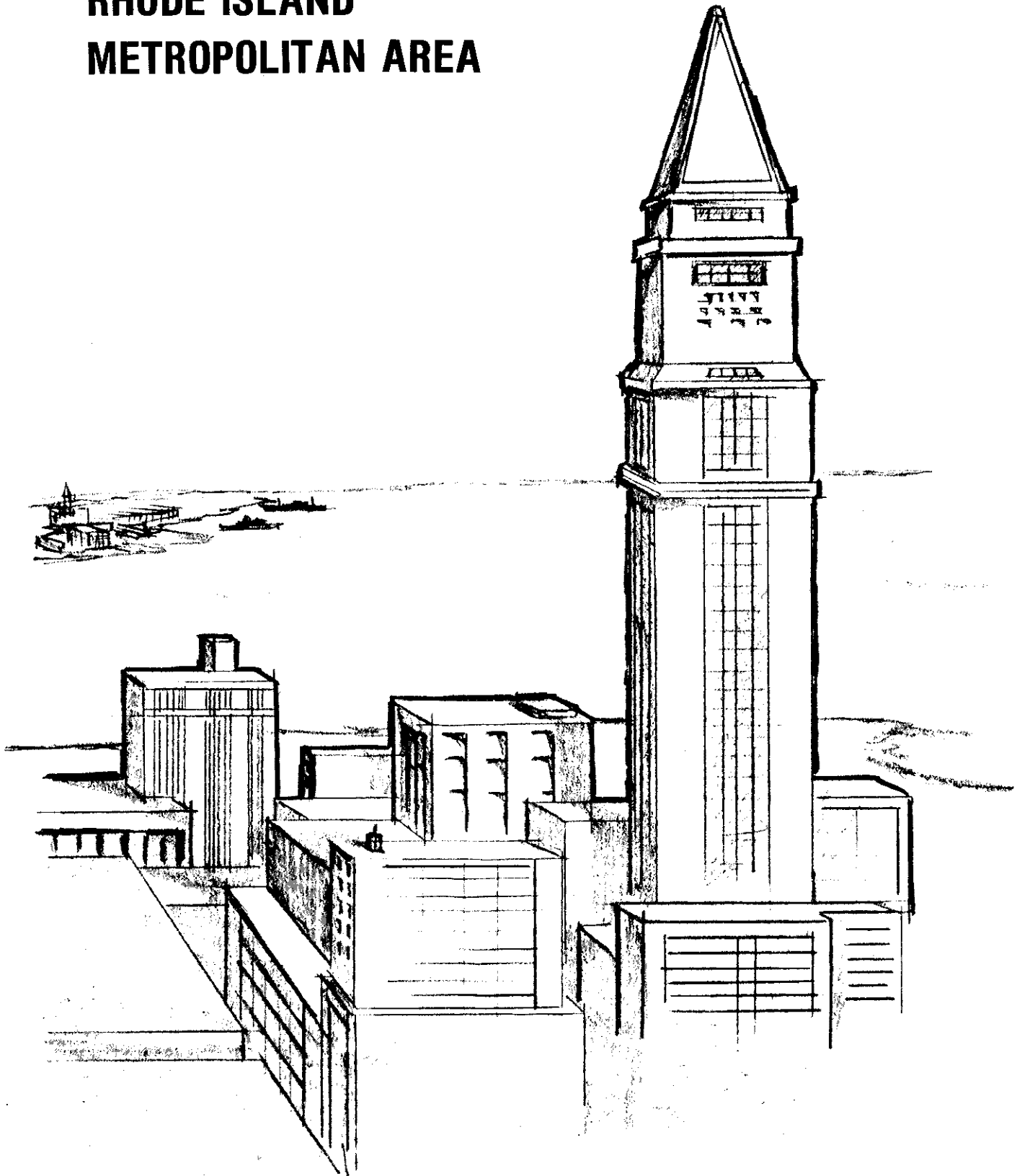
the metropolitan area. One of these alternative paths, the tunnel, would not be dependent on the availability of electricity to operate pumps, making the water supply system more reliable during periods of critical power demands, which often coincide with peak water demands. In addition, the higher quality of the water obtained directly from Hinckley, which requires less treatment, as compared to water withdrawn at Hyde Park, provides more reliable water quality.

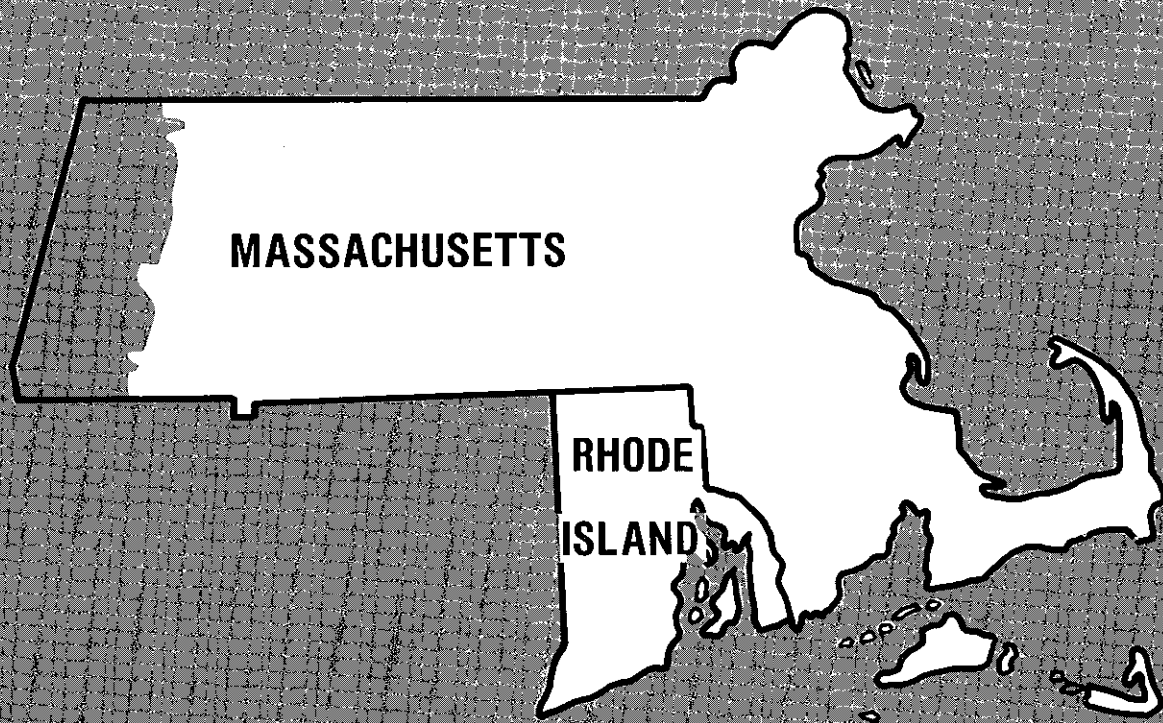
DISTRIBUTION OF EXPENDITURES FOR BRANCH 5



# CHAPTER 8

## EASTERN MASSACHUSETTS- RHODE ISLAND METROPOLITAN AREA





**FIGURE 8-1. EASTERN MASSACHUSETTS - RHODE ISLAND METROPOLITAN STUDY AREA**

## CHAPTER 8: EASTERN MASSACHUSETTS-RHODE ISLAND AND METROPOLITAN AREA (EMRI)

### BACKGROUND

The Eastern Massachusetts-Rhode Island (EMRI) Metropolitan Area consists of the entire state of Massachusetts except Berkshire County and the entire state of Rhode Island (Figure 8-1).

The NEWS water supply planning, since its initiation in the Eastern Massachusetts-Rhode Island area, has followed a stepwise approach. In 1967 and 1968, a series of small limited scope reconnaissance type reports were prepared to provide an overview of the New England water supply situation. On the basis of these reports, the EMRI area was identified as a region requiring early augmentation of existing supplies.

Following completion of the reconnaissance studies and meetings with water resource officials from Massachusetts, Rhode Island and Connecticut, and the New England River Basins Commission, a feasibility study on the EMRI water supply problems was made.

The water supply feasibility study completed by the NEWS Study in late 1969 (See Annotated Bibliography) describes the water supply problem of the Eastern Massachusetts-Rhode Island area. It includes details on the area's water demands projected through the year 2020, and presents a number of solutions to meet them. The most urgent demand for additional water supply appeared to be in the Greater Boston and Providence Metropolitan Areas.

Methods of meeting these future demands were presented in the feasibility study by means of illustrative regional plans. Although illustrative, these regional plans demonstrate the predominant role which development of

the Connecticut and Merrimack Rivers will have in meeting future water supply needs. Recognizing the role of these two major River Basins in meeting future needs allows an evaluation of the development priorities which should occur. On the basis of the analysis included in the feasibility study, early development of the Connecticut River Basin (to 1990) followed by later development of the Merrimack River Basin (1990-2020) appears to offer a cost effective means of meeting the region's needs. The Boston area demand appeared to be so great as to eventually require inter-basin diversions of 300 mgd or more from either or both the Merrimack and Connecticut River Basins.

At a meeting to discuss the feasibility report in May 1970, Federal agencies and representatives from Massachusetts, Connecticut, Rhode Island, and the New England River Basins Commission agreed on the direction of more detailed studies. Of prime concern was the near-term (prior to 1990) water supply problem of the Eastern Massachusetts areas.

It was agreed that the Corps would study two projects in detail for diversion of less than 200 mgd from the Connecticut River Basin, investigate the use of the Merrimack River as a regional and local source of water supply, and determine the potential environmental impact of large diversions on the Merrimack and Connecticut River estuaries.

The May 1970 meeting was quite important, therefore, because it helped define the policies which would guide future water supply development within the EMRI area. Within Massachusetts, for example, this policy direction is aimed towards meeting short

range needs by local surface and ground water developments, together with the Northfield Mountain and Millers River Basin projects. This development to meet short term (1990) needs allows time to institute water conservation measures, carefully investigate Merrimack River use, and permit technological advances in such techniques as desalination and recycling which may be helpful in meeting the longer range (2020) supply demands.

In Rhode Island, that State has noted its preference for in-state development of its resources rather than connection to an interstate water system. Rhode Island's policy direction, therefore, follows a stage development of ground and surface water sources located principally in the Pawtuxet, Blackstone and Pawcatuck River Basins.

The projects selected for further NEWS Study at the May 1970 meeting are in keeping with Massachusetts' general policy direction and are considered as components of the EMRI regional plan. Actions by others involved in the region's water supply planning have also added other components. These include proposals advanced by the Commonwealth of Massachusetts, the state of Rhode Island and regional planning agencies. The NEWS efforts, together with work done by its state and regional planning partners, have developed a de facto 1990 plan to meet short range water supply needs. This plan is generally represented by the projects shown on Branch 3.

For the longer range time frame (1990-2020) there is no regional plan which has been "set in concrete." The long range nature of water supply needs dictates that a flexible course of

action be maintained. However, even though a firm plan has not been adopted, the general direction which this long range plan will follow is well defined.

As noted earlier, key sources for meeting future water needs are the Connecticut and Merrimack River Basins. In Branch 3, the Connecticut Basin in the regional plan would be called on to supply 1990 needs. With early development of the Connecticut, the feasibility study indicated, the more economical source for long range (1990-2020) needs would be development of the Merrimack.

In 1974, reports were completed on the two Connecticut River diversion projects (Northfield Mountain and Millers River Basin). Studies indicated that the projects, as finally formu-

lated, could provide an additional 148 mgd of water supply with minimal risk of environmental damage. The project reports have been reviewed and recommended for implementation by the Board of Engineers for Rivers and Harbors.

If the Connecticut River Basin projects described above and other State and locally sponsored development shown on Branch 3 are not implemented, then other choices will have to be substituted. In the Decision Tree which is shown later, two other branches have been developed from projects reported in the original feasibility study. The intent of Branches 1 and 2 is not to suggest that these are preferred routes, but rather to display alternative paths which might be followed if the projects on Branch 3 were not implemented.

## AREA PROFILE

The EMRI area consists of Rhode Island and all of Massachusetts except Berkshire County. The region contains 357 municipalities and a population of 6.5 million. The population is expected to increase to 9.7 million by 2020. Of the current population, about 85% is urban.

The Boston area is the most significant element of the EMRI Area in terms of the demand exceeding the safe yield of existing systems. It is geographically and economically the center of the largest employment and population cluster in New England. Boston, the central city, is the Capital of Massachusetts and the most populous city in New England.

Population growth near the major metropolitan areas is expected to increase at a more rapid rate than in other sections, with the largest increases most likely to occur near the urban centers of Boston and Providence.

**TABLE 8-1**  
**COMPARISON BETWEEN EXISTING OR PROJECTED DEMAND<sup>1,2</sup>**  
**AND YIELD — EMRI (in mgd)**

		1965	1980	1990	2000	2020
Population (Millions)	Mass.	5.1	6.1	6.7	7.3	8.4
	R.I.	0.9	1.0	1.1	1.2	1.3
	<b>TOTAL</b>	6.0	7.1	7.8	8.5	9.7
Water Demand	Mass.	660	953	1,140	1,349	1,674
	R.I.	89	123	147	170	219
	<b>TOTAL</b>	749	1,076	1,287	1,519	1,893
Yield of Existing Water Systems	Mass.	813	813	813	813	813
	R.I.	160	160	160	160	160
	<b>TOTAL</b>	973	973	973	973	973
Deficit or Over Supply	Mass.	(153)	133	325	536	861
	R.I.	( 71)	3	20	44	59
	<b>TOTAL</b>	(224)	136	345	580	920

<sup>1</sup> Based on gpcd values by county shown in 1969 Feasibility Report and Obers Series E population projections.

<sup>2</sup> Deficit or over supply figures do not agree numerically with differences between Water Demand and Existing Yield due to local supplies, and an imbalance of local supply with local deficits.

## WATER DEMANDS

As shown in Table 8.1, the average water demand in the area in 1965 was nearly 750 mgd. This demand may reach about 1,080 mgd in 1980; 1520 mgd in 2000; and 1890 mgd by 2020. Of the expected demand, fully 75% is expected to occur in Massachusetts counties east of Worcester County. About 80% of the Rhode Island requirement will come from the counties in and adjacent to the Providence Metropolitan Area. The importance of meeting this increase in demand is underlined by the fact that 96% of the total population in the area depends upon public systems as their sole source of water supply. The study of the EMRI area began with an analysis of the balance between water demand and the yield of the existing water systems. Table 8.1 shows this comparison.

The projected demand as expressed in gallons per capita per day (GPCD) varies throughout the EMRI area and

is subject to high seasonal variation. In Massachusetts this demand varies from a low of 100 in Franklin County in the year 1980, rising to 162 in 2020, to a high of 312 in Dukes County in 1980 rising to 395 by 2020. In Rhode Island the least demand in 1980 is projected for Newport County, 80 gpcd, rising to 125 in 2020 while the greatest demand of 135 gpcd is forecast for Providence County in 1980, rising to 176 in 2020.

As can be seen from Table 8.1, a deficit or demand for additional water will exist in the area as a whole in 1980. Most of the additional requirements occur in the Massachusetts portion of the area. In the Rhode Island portion deficits appear for the first time in 1990 and increase in later years. Local community deficits may appear earlier. Thus the area as a whole must be considered as one with urgent water supply problems, mainly in Massachusetts.

## AVAILABLE WATER

There are 369 public water supply systems within the area with a combined safe yield of about 970 mgd, or about 140 mgd less than the expected demand in 1980.

The Metropolitan District Commission (MDC) of Massachusetts is the largest regional system in New England. This system supplies either all or part of the water in 42 communities including Boston. The MDC served about 2 million persons, or 37% of the Commonwealth's 1970 population.

MDC relies solely on surface water for its supply. Its three major reservoirs, Quabbin, Wachusett and Sudbury, impound flows in the tributaries of the Connecticut and Merrimack River Basins. Quabbin, with a capacity of 412 billion gallons, is the backbone of the system. It impounds the runoff from 186 square miles of the Swift River watershed and flow diverted from 98 square miles of the Ware River watershed, both tributaries

of the Connecticut River. It appeared, until the recent occurrence of larger than normal inflows, that Quabbin could be dry by 1985 and unusable at some point before then. If precipitation had not been above normal recently, such could have been the case.

Safe yield of the MDC system is about 300 mgd and average daily use in 1974 was 303 mgd. Of the 1974 demand, about 270 mgd was delivered to municipalities that rely exclusively on MDC as their only supply source. As per capita water use continues to increase and more communities join, or otherwise become dependent upon MDC, the system will be put under increasing strain. At the same time, any drought or failure in the MDC system will have severe and far reaching ramifications. Historically, surface water has been the principal source of supply for the area. Several river basins, contained either wholly or partially within the area, have potential for economical development of additional water supply sources. These potential sources are the basins of the Connecticut, Merrimack, Ipswich, North, Taunton, Pawtuxent, Blackstone, Thames, and Pawcatuck Rivers. Together, they have a total drainage of about 18,100 square miles and an average annual runoff of 19,400 mgd.

Although the combined runoff of these River Basins appears to be enough to meet all water supply requirements, there is an acute shortage of developed facilities to tap that supply. Unfortunately major use areas do not coincide geographically with the major water sources.

The following sources are being considered for development.

### The Connecticut

The Connecticut River Basin, with a drainage area of 11,265 square miles and an average annual runoff of 12,400 mgd is the largest in New England. The total developed yield of the Basin is only 260 mgd. The River

rises in the Third Connecticut Lake in northern New Hampshire near the Canadian border. From the lake, the river flows south through New Hampshire, Vermont, Massachusetts and Connecticut for about 400 miles to its mouth on Long Island Sound at Saybrook, Connecticut. Water from the Basin has long been used for supply by Basin communities and for interbasin transfer to Boston and the surrounding area.

### The Merrimack

The Merrimack River Basin lies in central New England and extends from the White Mountain region of New Hampshire south to the east central region of Massachusetts. It has a total drainage area of 5,010 square miles and an average annual runoff of 4,900 mgd. In 1965, total developed yield of the Basin was only 170 mgd, with only 20 mgd drawn from the mainstem.

Many tributaries of the Merrimack in the study area have been used as water supply sources, with the MDC Wachusett and Sudbury reservoirs representing the major projects.

Although the mainstem of the Merrimack has a large potential for water supply, municipalities have shunned the River because it is highly polluted with industrial and municipal waste. For many years, the only major user of the River was the City of Lawrence. Recently, however, Lowell has also begun to use the River for water supply because of the scarcity of other sources.

Similarly, as water demands increase and cleaner local sources prove inadequate, more communities, both in the Basin and beyond it, will be forced to tap the Merrimack for supply.

Available additional major storage reservoir sites within the Basin are scarce and appear expensive. However, the large flows of the mainstem itself provide an opportunity for use by direct withdrawal and treatment of high flows.

### **Blackstone River Basin**

The Blackstone River Basin headwaters are located in central Massachusetts. From there the River flows in a generally southeasterly direction to Pawtucket, Rhode Island, and then southerly to its mouth at the Providence River. Total drainage area of the Basin is 540 square miles with an annual runoff of 59 mgd. Present water quality within the Basin is generally poor to fair. However, some small tributaries possess good quality water.

Two tributaries, Nipmuc River and Tarkiln Brook, of the Blackstone River could be developed.

### **Ipswich River Basin**

This Basin, located on the Massachusetts North Shore, is one of a series of small coastal rivers which drain the eastern Massachusetts region. It has a drainage area of 155 square miles and an annual runoff of 160 mgd. At present, water quality within the Basin is generally good and the runoff from the Basin is heavily used for water supply purposes with the majority of supply exported from the Basin to nearby communities.

### **North River Basin**

The North River Basin is located on the Massachusetts South Shore. At present, the river is one of the few Eastern Massachusetts basins that is relatively undeveloped. It has a drainage area of 68 square miles and an average annual runoff of 74 mgd.

### **Pawcatuck River Basin**

The Pawcatuck River Basin is located in the southwestern part of Rhode Island and Connecticut. The watershed of the Basin totals 303 square miles with an average annual runoff of 364 mgd. Existing water quality in the Pawcatuck is generally good, although some reaches of the mainstem River are classified as poor.

### **Pawtuxet River Basin**

The Pawtuxet River Basin is located in the northern half of Rhode Island. The River drains an area of 230 square miles, all of which lies within Rhode Island with an average annual runoff of 290 mgd. In general, most of the Basin's streams are of good quality; however, lower reaches of the mainstem River are classified as poor. The hilly topography of the watershed has in the past lent itself to the development of water supply reservoirs, and the Providence Water Supply Board's sources are located within this River Basin.

### **Thames River Basin**

The Thames River Basin lies principally in the eastern part of Connecticut, with portions extending into south central Massachusetts and northwestern Rhode Island. The drainage area of the Basin is 1,474 square miles with an average annual runoff of 1,658 mgd.

Present water quality in the Basin's streams range from poor to good with the Rhode Island portion of the Basin classified as good.

### **Taunton River Basin**

The Taunton River Basin is a moderate size coastal basin that drains portions of Bristol and Plymouth Counties in southeastern Massachusetts. Its total drainage area is 543 square miles with an average annual runoff of 635 mgd. Existing water quality within the Basin varies from good in some headwater tributaries to poor in the lower reaches of the mainstem River.

### **Groundwater**

Small yields can be developed from wells in most of the till or bedrock aquifers that underlie Massachusetts and Rhode Island. However, they would be of minor regional importance because they are capable of sustaining only relatively small yields, more suitable for local demand. There are, however, a few areas where

groundwater could be developed enough to make it an element in a regional scheme. The most notable of these sites are Barnstable and southeastern Plymouth Counties. In these and other regions suitable for possible ground water development, the quality of the water is quite good.

### **WATER SUPPLY PROGRAMS**

During the planning activities in the New England area, officials and citizens in the area expressed a desire to meet water demands in concert with several additional objectives. One strong point stressed by New England officials was their desire to avoid the construction of any new reservoirs that would remove land from use, displace people, and possibly involve environmental damage. Therefore, planning in the New England area has stressed the possibility of adding to existing systems, using existing reservoirs, and capitalizing on the high spring river flows wherever possible.

Within Southeastern New England, as in the other most critical areas, planning to meet growing water demands is continuing. The planning to date, however, has revealed that the Connecticut and Merrimack River Basins, because of their size and location, will undoubtedly be called upon to furnish significant quantities of future water supply to the region.

As illustrated on Figure 8-2, the timing and sizing of facilities for development will depend on the branch selected. For example, if Branch 3 were selected, then critical short term demands would be largely met through development of locally available supplies. During the early time frame, limited development of the Connecticut River Basin would be necessary. In the mid-range years, 1990-2000, locally available supplies may again furnish a major portion of the needed supply. Further development of the Merrimack and/or Connecticut during this time period could be alternatives to

local development. By the long-range target years of 2000-2020, however, development of the Merrimack or Connecticut River Basins or both will probably be required to meet future water needs. Development can be delayed or reduced if local interests can implement a demand reduction program through restrictions or water saving fixtures.

A review of branches 1 and 2 on the Decision Tree reveals similar dependence on the Connecticut and Merrimack River Basins as principal sources for the area's future supply needs. Major differences between branch 3 and branches 1 and 2 lie in the timing and scope of development for the two major River Basins. An irrevocable commitment to certain projects on one branch is not necessary. Different projects can be chosen for later time frames to complement the satisfaction of a variety of differing objectives. If demand reduction can be implemented by local interests not all projects may be necessary.

Branch 1 would require an early commitment to large scale development of the Connecticut River Basin. Branch 2, on the other hand, would require an early decision for heavy reliance on the Merrimack River. Branch 3, because of its dependence on locally available resources in the short to medium range target years, allows the decision regarding major commitments to development of the Connecticut and/or Merrimack Rivers to be made at a future date. Such a decision, of course, would have the benefit of advances in water supply technology and the latest economic and demographic trends.

The purpose of discussing the relationship of the Connecticut and Merrimack River Basins is to present the source-supply situation that NEWS investigations have revealed. It is especially important to appreciate the significance of the Merrimack and Connecticut Basins to the region when two special issues are considered.

A special issue that must be considered by decision makers is Massachusetts' relationship with the State of Connecticut. This downstream state is opposed to further diversions by Massachusetts from the Connecticut River Basin. Before Massachusetts impounded the Swift River, a tributary of the Connecticut, to form Quabbin Reservoir in 1931, Connecticut brought suit to stop the diversion. The court decided in favor of Massachusetts.

Then, as now, Connecticut officials pointed out that even flood skimming might have detrimental effects on its portion of the River. Maintaining spring freshet (peak flows), according to the State Department of Environmental Protection, has benefits such as recharging ground water, replenishing of agricultural flood plain soils, flushing of sludge and silt deposits, maintaining wildlife and aquatic habitat and being a triggering mechanism for anadromous fish runs.

Connecticut has not officially opposed upstream diversions at the pumped storage hydroelectric project at Northfield Mountain as long as they do not diminish the flow at the gaging station at Montague City to less than 17,000 cfs. However, state officials feel that any diversion, even with this limitation, would set a precedent for further diversion. They have, meanwhile, called for an independent agency to be established to monitor diversions from the Connecticut River and for a formal mechanism to properly weigh the interests of all Basin states. Discussions toward establishing such a mechanism have already begun.

The second special issue is the possible upstream diversion of flow by New Hampshire from the Merrimack River Basin to serve the water needs of the coastal area. No detailed proposals have been formulated by New Hampshire on this project; however, feasibility detail plans have been prepared. On the basis of all information gathered to date, there appears to be few alternatives to such a diversion scheme.

Because there has been no definite proposal advanced by New Hampshire, Massachusetts has not offered an opinion of such a plan. In the future, however, the Merrimack Basin may be needed as a major source of supply for Massachusetts. In this case, a possible conflict between New Hampshire and Massachusetts could develop.

Many projects were investigated and found technically feasible, as reported in the Draft Report *Feasibility Report in Alternative Regional Water Supply Plans for Southeastern New England* prepared in November 1969, by the New England Division, Corps of Engineers. Not all of these projects have been investigated to the same degree of detail, however. The projects shown are illustrative, and they do reflect the region's major sources of water supply and the choices available to meet future water supply needs. These projects are summarized here, organized in groups based on the source from which water is drawn.

### Connecticut River Basin

Seven possible methods of developing additional water supply from the Connecticut River Basin to aid in meeting the region's future water supply needs were investigated. Five of the projects considered would aid in meeting out-of-Basin needs in Eastern Massachusetts as well as portions of the in-Basin needs. All of the projects considered are high flow diversion projects. Water would be delivered through aqueduct systems for storage in the existing Quabbin Reservoir. From Quabbin, the water could then be delivered to communities principally located in Eastern Massachusetts.

**Northfield Mountain Project.** A small portion of the annual spring runoff of the mainstem Connecticut River would be diverted to Quabbin Reservoir for use as water supply. These mainstem flows would be diverted via an existing pumped storage hydroelectric facility at Northfield Mountain.

tain, Massachusetts. The possibility of changing the pumped storage project to include water supply is currently being negotiated by electric utility officials and the Metropolitan District Commission.

Modification of the hydroelectric operating schedule to add the water supply function would consist of extending the daily pumping cycle of the 12,000 cfs reversible turbines 1.4 hours during highflow periods. This additional period is considered the idle time for the power installation between its pumping and generating cycles. The additional 375 million gallons pumped during this 1.4 hours would then be stored for water supply on top of the water stored for power generation in the Northfield Mountain pumped storage reservoir.

The additions required to develop the project for water supply would consist of additional storage in the power pool; an 8.5-mile, 10-foot-diameter connecting tunnel to Quabbin Reservoir; disinfection units and minor appurtenant structures. The estimated safe yield of this project is 72 mgd.

*Millers River Basin Project.* This project would divert water by highflow skimming from the Millers River Basin, a tributary of the Connecticut River, which lies generally north of Quabbin Reservoir. An 8-foot-diameter tunnel would be built from the existing Tully Flood Control Dam and Lake to carry the withdrawn high flows from the Tully River to the Millers River. At the Millers River above Athol, Massachusetts, an intake would divert the water from the Millers to a 10-foot-diameter, 9.5-mile tunnel to Quabbin Reservoir. Because water in the Millers is presently heavily polluted, this project includes waste treatment plants upstream from the river intake. This project would provide an additional 76 mgd of safe yield to the Quabbin Reservoir system.

*Hadley Project.* This project would develop additional yield via high flow

skimming techniques through an intake works near Hadley, Massachusetts. Water withdrawn from the mainstem of the Connecticut would be pumped to Quabbin Reservoir through a 9.8-mile, 10-foot-diameter tunnel. This project would add an estimated 72 mgd of additional yield to the Quabbin Reservoir system.

*West Deerfield Project.* An additional 72 mgd would be made available by high flow skimming from the Deerfield River, a tributary of the Connecticut. The intake works for this project would be located on the Deerfield near West Deerfield, Massachusetts. Because the natural river bed at this location is shallow, construction of a 200-foot concrete weir would be required to insure depth control. The diverted water would be pumped via a 14.2-mile, 10-foot-diameter tunnel to Quabbin.

*Connecticut River Diversion (500 mgd).* The project that would be constructed would high flow skim water from the mainstem Connecticut near Hadley, Massachusetts. Water withdrawn would be delivered to Quabbin, via pumping through a 26-foot-diameter tunnel 9.8-miles-long. A new tunnel 24.2 miles long, would connect the Wachusett and Quabbin Reservoirs. From Wachusett, a new 14.1-mile-tunnel may be needed to connect to the existing adueduct system. Quabbin Reservoir might require some enlargement.

*Connecticut River Diversion (550 mgd).* This project is similar in concept to the preceding one. In this plan, however, the diversion for 550 mgd would serve as an alternative to several projects considered to serve Bristol County, Massachusetts.

*Connecticut River Mainstem — Hampden County.* This project would use direct withdrawal of 20 mgd from the mainstem Connecticut. An intake structure would be built above Holyoke Dam and water withdrawn

would be treated in a water treatment plant and pumped to Hampden County, Massachusetts through a 7.4-mile, 48-inch-diameter pipe.

*Knightsville Reservoir Project.* This project would require the reconstruction of an existing flood control reservoir in the Westfield River Basin. Water would be used to meet in-Basin Connecticut River future supply needs. The recreation pool would be drawn down during off-season periods and delivered to the existing water supply pool at Littleville Reservoir, an existing reservoir located on an adjacent tributary of the Westfield River. Water delivered to Littleville Reservoir would then be conveyed through an existing force main to the Cobble Mountain-Borden Brook complex, the existing main source for the Springfield, Massachusetts water system. The safe yield from development of Knightsville Reservoir would be 20 mgd.

#### **Merrimack River Basin**

Five projects were investigated which would develop resources of the Merrimack River Basin to meet a portion of the study area's projected future water needs. The service areas vary from municipalities near the River to out-of-Basin areas in eastern Massachusetts.

*Merrimack River at Lowell.* Two projects designed to meet largely in-Basin needs would yield from 35 to 50 mgd. The first project, for 35 mgd, was designed to meet short-range supply needs in communities located within northern Middlesex and northern Essex Counties. Development would require construction of pumping installations, a water treatment plant and a 15-mile, 36-inch diameter transmission main. Depending on the operating schedule selected, a small quantity of upstream reservoir storage might also be needed.

The second project, if developed, would meet in-Basin needs as well as

out-of-basin needs in the adjoining Ipswich and Parker River Basins. This 50 mgd project would service municipalities in northern Middlesex and most of Essex Counties. Facilities necessary to develop this yield would include intake works, pumping installations, a water treatment plant and supply transmission lines. Communities near the treatment plant could draw their supplies from the plant itself. Municipalities downstream and in the Ipswich River Basin would be supplied through 15 miles of 48-inch-diameter and 9 miles of 30-inch-diameter pipeline.

*Merrimack River for Eastern Massachusetts.* Three projects to meet future out-of-basin needs were evaluated. In these projects, two methods of supplying the eastern Massachusetts Metropolitan region from the Merrimack River were considered. The primary method considered diverting flow from the Merrimack when river flow is in excess of other water resource requirements, such as that needed for established water quality standards.

Withdrawal from the river would be used to maintain maximum storage in Quabbin and Wachusett Reservoirs. During high flow periods in the Merrimack River, water demands within the consumer area would be met partially or wholly by diversions from the Merrimack River. During low flow periods, when flows are lower than those necessary for allied water resource uses, no diversions would be made from the Merrimack. During such periods, water supply needs would be met by drawing water from Quabbin and Wachusett Reservoir storage. This project reduces upstream storage reservoir requirements.

Alternative No. 2 would use the Merrimack River as a water supply source on a year-round basis. In this plan, water would be diverted, treated and delivered daily. During periods of low flow, water would have to be released

from upstream reservoirs to compensate for the low flow withdrawals.

Development of additional yield from the projects can range from 170 to 622 mgd. In order to fully develop yield, needed facilities would include intake works on the Merrimack River, a major water treatment plant and 92 miles of varying diameter tunnel within the Boston Metropolitan complex and a connecting 14-mile tunnel aqueduct from Wachusett Reservoir to the transmission aqueduct loop. If Alternative No. 2 were used then several upstream reservoir sites would also be required.

#### **Ipswich River Basin**

In this project, the Ipswich River would be further developed by high flow skimming from the mainstem to four off-stream reservoirs. The available yield is estimated to be 15 mgd. This project would require construction of four off-stream reservoirs, diversion aqueducts, a pumping installation, a water treatment plant and a force main connecting the reservoirs to the treatment plant.

#### **North River Basin**

This project would require construction of a dam and reservoir in the tidal range of the North River, a water treatment plant, pump stations and connection pipelines to the northern half of Plymouth County, Massachusetts. Additional available yield is estimated to be 25 mgd.

#### **Taunton River Basin**

Two projects would skim the high flows of the Taunton and deliver it to off-stream storage facilities.

One project would divert water from the Taunton to existing storage at the Lakeville Ponds complex. The second

project would deliver diverted flows to a proposed reservoir site, known as Copicut Reservoir.

Water from either of the off-stream storage sites would be treated and delivered via transmission facilities to communities in southeastern Massachusetts. Potential yield would be 25 mgd.

Further development of the Taunton could be accomplished by construction of a dam and reservoir in the lower reaches of the River. The site selected for this project is located near the river mouth within the tidal estuary portion of the Basin. This facility would yield about 97 mgd for Bristol County, Massachusetts and perhaps portions of Rhode Island.

#### **Pawtuxet River Basin**

The Big River Reservoir project would develop the Big River watershed for 29 mgd by construction of a dam and storage reservoir on the mainstem of the River. Water drawn from storage would be treated and conveyed via force mains to existing transmission lines of the Providence system.

Construction of the Big River dam would provide 82,000 acre-feet of additional storage. Water drawn from the reservoir would be conveyed in a 1.1-mile 90-inch-conduit to the water treatment plant. Finished water from the treatment plant would be conveyed to existing transmission mains through a 4.5-mile, 84-inch-diameter pipe and a 2-mile 10-foot-diameter tunnel.

The adjoining watershed, Flat River, has limited storage sites and transfer of water from the Flat River via high flow withdrawal could increase the dependable yield of Big River Reservoir. Additional yield from this project is estimated to be 13 mgd.

### Thames River Basin

Development of the Thames River Basin within Rhode Island would consist of high flow withdrawals from the Moosup River to a small regulating reservoir and then to Big River Reservoir.

The major components of the Moosup River diversion would consist of a diversion dam on the Moosup and pumping facilities with connecting aqueduct to the Big River Reservoir to develop a yield of 20 mgd.

### Pawcatuck River Basin

The project investigated in the Pawcatuck River Basin would develop a tributary, the Wood River. The Wood development, similar to the Moosup project described earlier, would flood skim and deliver water to the Providence area via the Big River Reservoir.

The major components of the Wood project are an initial diversion dam and intake structure, pumping facilities and a connecting aqueduct from the intake to the Big River watershed. Eventually, as demand increases, a dam and reservoir could be built to develop the maximum potential of this source.

Flow would be diverted from the Wood through a 4.2-mile, 48-inch-diameter pipeline to the Big River Reservoir. The additional yield would be 19 mgd. If a 13,500 acre-foot reservoir was ultimately added to the system, the Wood River system total yield would be 30 mgd.

### Blackstone River Basin

Two tributaries, the Nipmuc River and Tarkiln Brook, of the Blackstone River would be developed for a combined

yield of 14 mgd. The area to be serviced by these projects would be northern Rhode Island.

The projects would develop Tarkiln Brook by construction of a dam and reservoir, pumping facilities and a connecting aqueduct from the reservoir to a water treatment plant. Initially, additional yield from the Nipmuc River would be made available by high flow withdrawals. As water demands increase, construction of a storage dam and reservoir on the Nipmuc itself would allow the development of the project's full potential yield.

In the operation of this project, water would be diverted from the Nipmuc and delivered to a reservoir on Tarkiln Brook through a 4.3 mile, 30-inch-diameter conduit. Water from the reservoir would be treated and conveyed 12 miles through pipelines to major distribution points.

### Southeastern Massachusetts Groundwater

An investigation of the potential ground water resources was conducted by the United States Geological Survey (USGS) as input to the NEWS Study. In their analysis, the USGS did not undertake any new ground water research, but made use of available data from prior reports.

The USGS analysis outlined two regions that may possess sufficient groundwater resources for regional supply. Other areas were identified as having potential groundwater sources capable of meeting local requirements.

The areas identified for possible regional supply were Southeastern Massachusetts and South Central Rhode Island.

The groundwater aquifer of Southeastern Massachusetts lies within the watersheds of a number of small coastal streams. Available data indicates that groundwater quality is generally good. However, the area has a history of iron and manganese increasing in concentration in existing wells over a period of time. The increased iron and manganese content has caused abandonment of some wells.

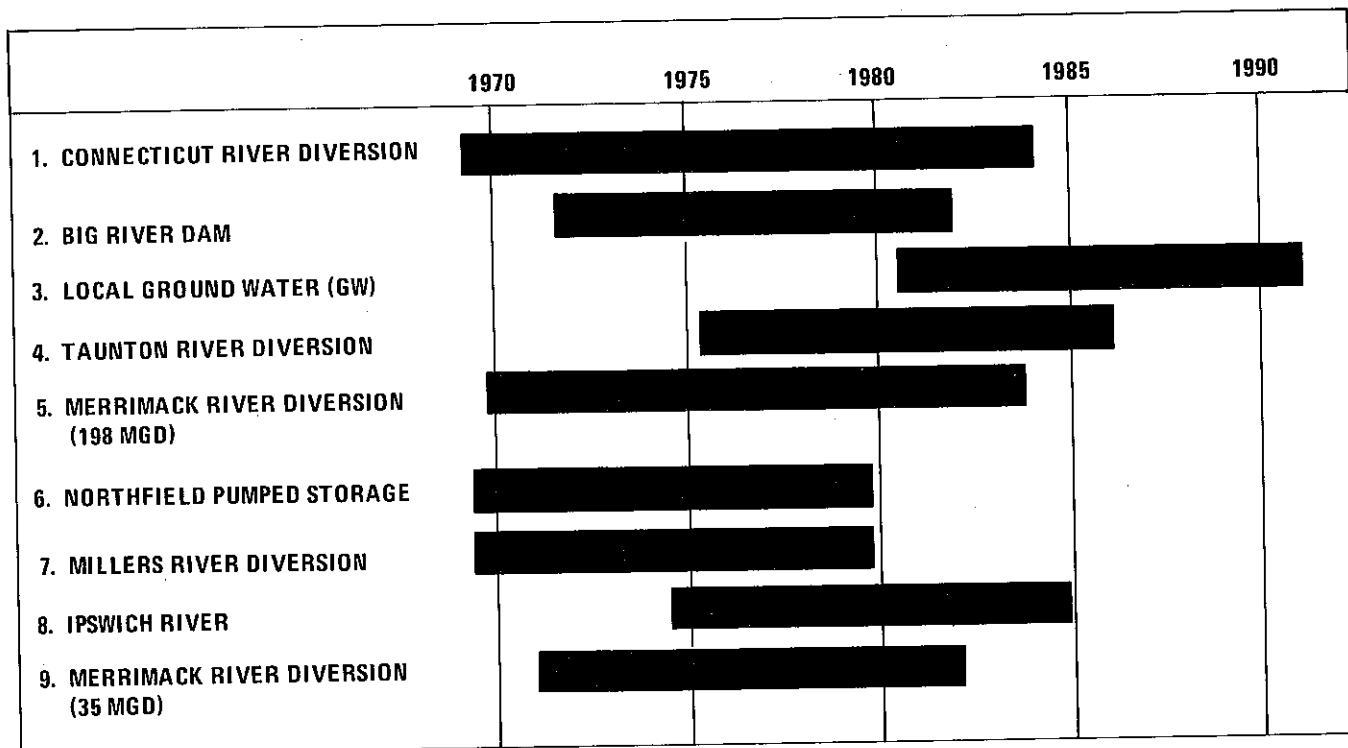
One project would develop and supply an average yield of 12 mgd to the northern portion of Plymouth County, Massachusetts. Necessary facilities include well fields, pumping stations, transmission mains from well fields to municipalities, and water treatment plants.

Water withdrawn from wells would be delivered to an iron and manganese removal treatment plant. From there, the water would be transported through a 36-inch-diameter conduit, 23 miles to Northern Plymouth County.

The second project would develop 28 mgd for municipalities in Bristol County. Facilities needed include well fields, booster pumping stations, water treatment plants and connecting transmission aqueducts to communities.

Water withdrawn from the wellfield would be delivered to an iron and manganese water treatment plant. Following treatment, the water would be delivered through 30 miles of varying diameter pipelines.

The groundwater from the upper Pawcatuck River Basin has the potential of meeting the demands of South Central Rhode Island as well as the two islands



#### LEGEND

A LOCAL, STATE, FEDERAL APPROVAL  
 B FUNDING FOR ENGINEERING DESIGN  
 C FUNDING FOR CONSTRUCTION

\* PROJECT ON LINE  
 \*\* NOTE THAT MANY DECISIONS APPEAR LONG OVERDUE

FIGURE 8-2. DECISION TIMING FOR INITIAL PROJECTS\*\*—EMRI

of Jamestown and Newport. Development of 11 mgd from well fields located on the mainland could be piped to existing systems on the islands.

In this project, water would be conveyed by two 20-inch mains from the wellfield to a collection point. A 24-

inch transmission main would carry the water 14 miles to the Jamestown-Newport water distribution system.

#### DECISION TIMING

The timing involved for implementation of each project is an important factor to consider when selecting projects for inclusion in a program. The

schedules of implementation shown in Figure 8-2 are for those early action projects in each branch of the Decision Tree. Figure 8-2 illustrates the point in time at which decisions should have been made to overcome current deficits and to reduce the risk of additional shortages.

Projects shown on the "Decision Timing Chart" labeled as No. 1, No. 5,

No. 6 and No. 7 are alternative projects which would meet short range needs of the Metropolitan Boston region. Demand currently exceeds safe yield and immediate augmentation of available supplies is necessary. Since the Federal, State and local approval dates have already passed, a decision on these project elements is overdue.

The project shown as No. 2 "Big River Dam" is required about 1981, according to state officials, in order to maintain an adequate supply reserve. In order to meet the 1981 target date, necessary approvals should have been secured by 1972.

The project shown as No. 3 "Local Groundwater" according to latest estimates would meet needs developing after 1990. To have this project on line when required, necessary approvals would have to be secured by 1981 at the latest.

The project shown as No. 4 "Taunton River Diversion" according to latest estimates would meet regional needs about 1985. In order to have this project on line when necessary, approvals would be required by 1976.

The project shown as No. 8 "Ipswich River" is presently under investigation by Massachusetts State officials. It is expected that approval for one project reservoir may be secured by 1975 or early 1976.

The project shown as No. 9 "Merrimack River Diversion (35 mgd)"

would meet needs which affect the region about 1981. Necessary approvals for this project element were required in 1972 in order to meet forecast needs. The decision is past due on this project.

### PLANNING ASSUMPTIONS

Planning in the area has been keyed to a strong desire by officials and citizens to avoid any new reservoir construction.

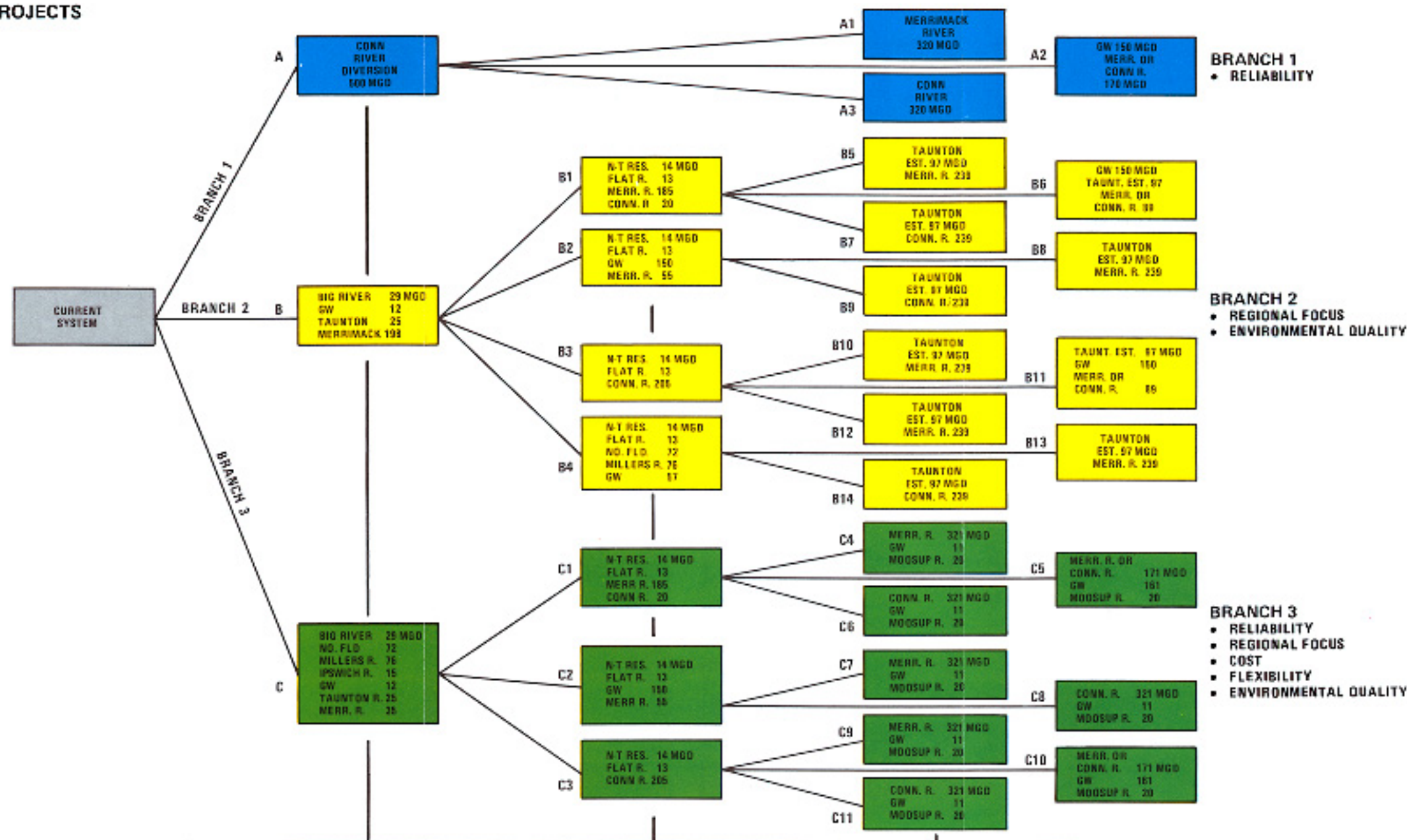
Three alternative water supply programs for the EMRI area, reflecting the additional objectives voiced by area citizens and officials, have been formulated as shown in Figure 8-3 and were developed on the basis of the following assumptions:

1. An urgent water supply need exists and the deficit will get larger.
2. Water supply projects will be necessary despite use of water saving fixtures or appliances.
3. Water supply sources should be developed to meet the base load demand rather than peak demands.
4. Water use restrictions will be of limited value in reducing base load demand.

### COSTS AND CASH FLOW

Local expenditure and cost data have been developed and are displayed for decision tree branches 1 through 3. These data demonstrate the financial sensitivity of program and user costs to local and extra local funding source assumptions. Comparison of estimated annual local expenditures through 2020 for both amortized capital construction costs and operation, maintenance and repair costs shows that it is less expensive to use extra local funding during the 50 year period (1970-2020) of analysis. This analysis was based upon the assumption that the 1958 Water Supply Act may be applied to obtain extra local funding. It includes a lower interest rate and a longer payback period, resulting in smaller annual payments, as well as an initial period of up to ten years during which no debt service payments are made and no interest is accrued. However, since in all cases local expenditures extend beyond 2020, total program expenditures are slightly greater, less than 1%, with extra local funding. Estimated cost per mgd safe yield for 1980, 2000 and 2020 is higher for local funding because it has been calculated on the basis of a 10% reserve on debt service which is typically required by investment bankers on municipally funded projects.

FIGURE 8-3 DECISION TREE – EMRI PROJECTS



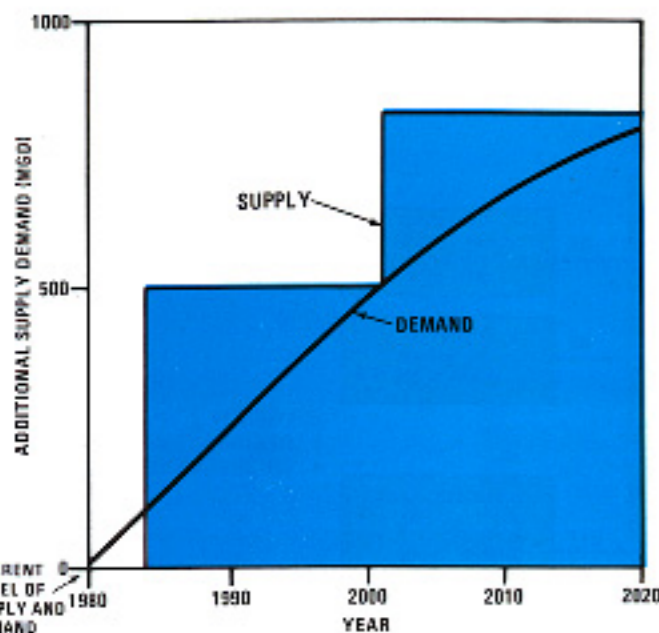
\*Approximately 100 mgd of the deficit shown in Table 8-1 should be met by the year 2020 through small, locally developed sources in the rural areas of western Massachusetts, Dukes County, Nantucket County and Cape Cod in Barnstable County.

BRANCH	THROUGH 1990			THROUGH 2000			THROUGH 2020		
	ADDITIONAL DEMAND 264 MGD			ADDITIONAL DEMAND 484 MGD			ADDITIONAL DEMAND 820 MGD		
	ADDITIONAL* SUPPLY MGD	LOCAL CASH FLOW		ADDITIONAL* SUPPLY MGD	LOCAL CASH FLOW		ADDITIONAL* SUPPLY MGD	LOCAL CASH FLOW	
		LOCAL	EXTRA		LOCAL	EXTRA		LOCAL	EXTRA
1	500	331.8	0	500	2599.5	1242.1	820	5008.6	3606.6
2	264	76.6	0	496	1266.7	745.6	832	3450.2	2590.4
3	264	53.1	14.3	496	1412.4	1330.8	848	3654.5	2587.3

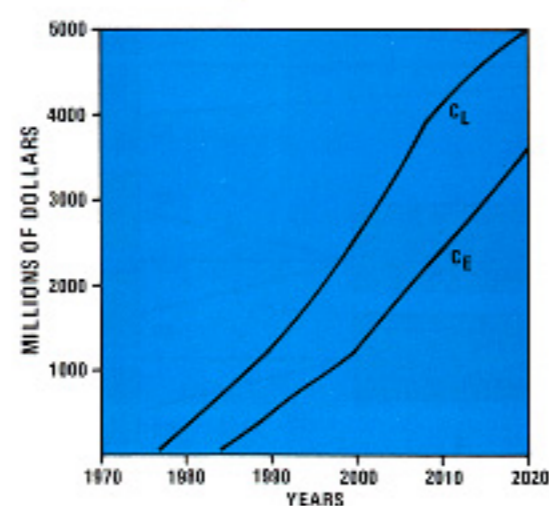
## LEGEND:

GW – GROUND WATER (WELLS)  
 N-T RES. – NIPMUC AND TARKILN RESERVOIRS  
 EST – ESTUARY WITHDRAWN WATER  
 TREATMENT PLANT

# ADDITIONAL SUPPLY DEMAND VS. TIME BRANCH 1

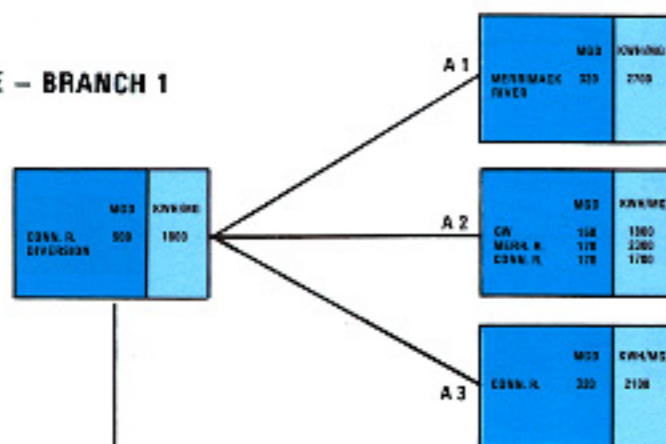


# CUMULATIVE EXPENDITURES FOR BRANCH 1



CL - Local expenditures under local funding assumption  
CE - Local expenditures under extra local funding assumption  
Curves are approximate in shape due to scale of graph

# DECISION TREE - BRANCH 1



YEAR	1990	2000	2020
ADDITIONAL DEMAND (MGD)	264	494	820
ADDITIONAL SUPPLY (MGD)	500	500	A1 - 820 A2 - 820 A3 - 820
ENERGY REQUIREMENTS* KWH/MG	1800	1800	A1 - 2200 A2 - 1900/1800 A3 - 1900

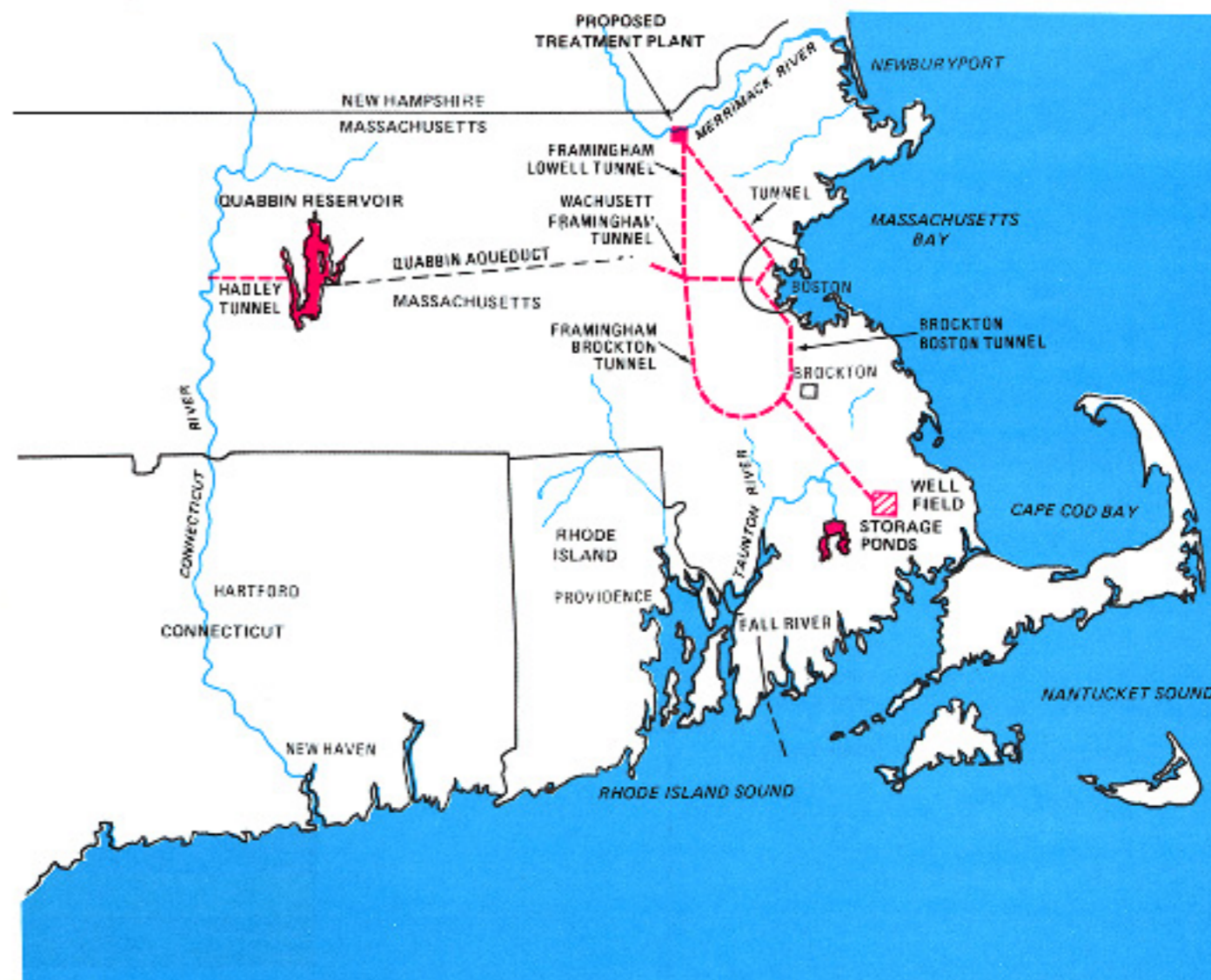
\*AVERAGE

# BRANCH 1

## RELIABILITY

### LEGEND:

- EXISTING STORAGE (POND, RESERVOIR, ETC.)
- PROPOSED PIPELINES, TUNNELS, CONDUITS, ETC.
- EXISTING PIPELINES, TUNNELS, CONDUITS, ETC.
- PROPOSED STORAGE (POND, RESERVOIR, ETC.)
- PROPOSED PUMPING STATION (OR WSTP)
- PROPOSED WELL FIELDS
- ESTUARY WITHDRAWAL (RIVER MIX WTP)
- WELLS
- HIGH FLOW SKIN INTERCONNECTION



**BRANCH NUMBER ONE** — A program designed to satisfy the objective of reliability as well as water supply.

The Branch 1 program emphasizes reliability of supply to meet demand. One project is included for the 1990–2000 time period, a diversion of 500 mgd from the Connecticut River.

Further projects may not be necessary for the years 2000–2020. However, additional diversions from the Connecticut and/or Merrimack Rivers, with a possible regional groundwater development could meet the regional needs.

#### Program Description

The project on Branch 1 would include a river intake, pumping and transmission facilities to divert 500 mgd from the Connecticut River to Quabbin Reservoir for the 1990–2000 time frame.

Projects considered for the longer term 2000–2020 demands could include a combination of regional groundwater development and/or diversions from either the Connecticut or Merrimack Rivers.

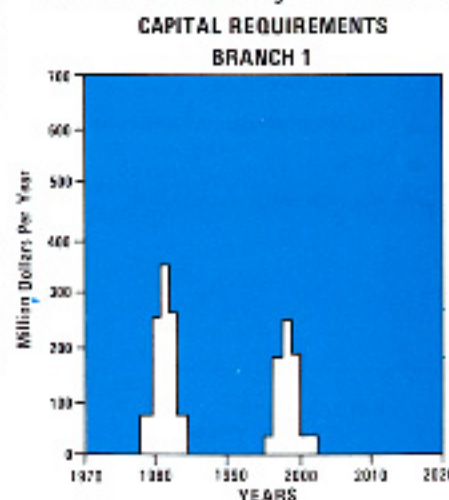
#### Program Rationale

The possibility of not having sufficient quantities of water to meet demand with this project in operation is negligible. The diversions would take place only when flows in the Connecticut were high and therefore, the River would retain its potential for downstream use.

Poor water quality in the River is unlikely in the future and therefore health risks are minimal. This is due to the expected impact of PL92-500, the Federal Water Pollution Control Act Amendment of 1972.

There is, however, a risk related to the timeliness with which this project could be implemented due to the objection of the State of Connecticut to any more diversions from the Connecticut River Basin. As noted earlier in this report, jurisdictional questions often require lengthy periods of time to resolve.

This project also has the potential for an adverse environmental impact on the reservoirs receiving the diversions.



Branch 1 would not require the implementation of any additional projects until the year 2000 or beyond, and would therefore allow about 25 years for the continued development and implementation of advanced wastewater technology which could promote significant reuse of treated wastewater both directly and indirectly. This could eliminate the need for the later project shown on Branch 1. In terms of capital and operating costs this is the most expensive alternative because of the large and lengthy transmission facilities necessary to bring the water to existing systems and the cost of power to pump the water through this transmission system. In terms of flexibility, Branch 1 offers little opportunity to build the major elements, i.e., the transmission lines, as modular units. It is inefficient to construct tunnels and major pipelines at intervals of less than 20 to 25 years. Therefore, a long term commitment must be made to the use of the project once it is implemented if proper efficiencies are to result. Considerable problems arise with Branch 1 as a result of the geographic focus of involved Connecticut officials, who believe that diversions reduce the opportunity for downstream use. Even though diversions might be small compared to river flows, Connecticut believes that a precedent for even larger diversions would be established. The inhabitants of Western Massachusetts seem to

prefer that the Greater Boston Metropolitan Area develop water supplies either within its boundaries or closer than the Connecticut River Basin. The MDC already diverts 195 mgd from the Connecticut Basin through the Quabbin Reservoir System. Therefore, questions of equity are being raised over increased diversions from the Basin.

The advantage of this branch is that the large-scale development will insure an adequate supply of water for the mid-range future.

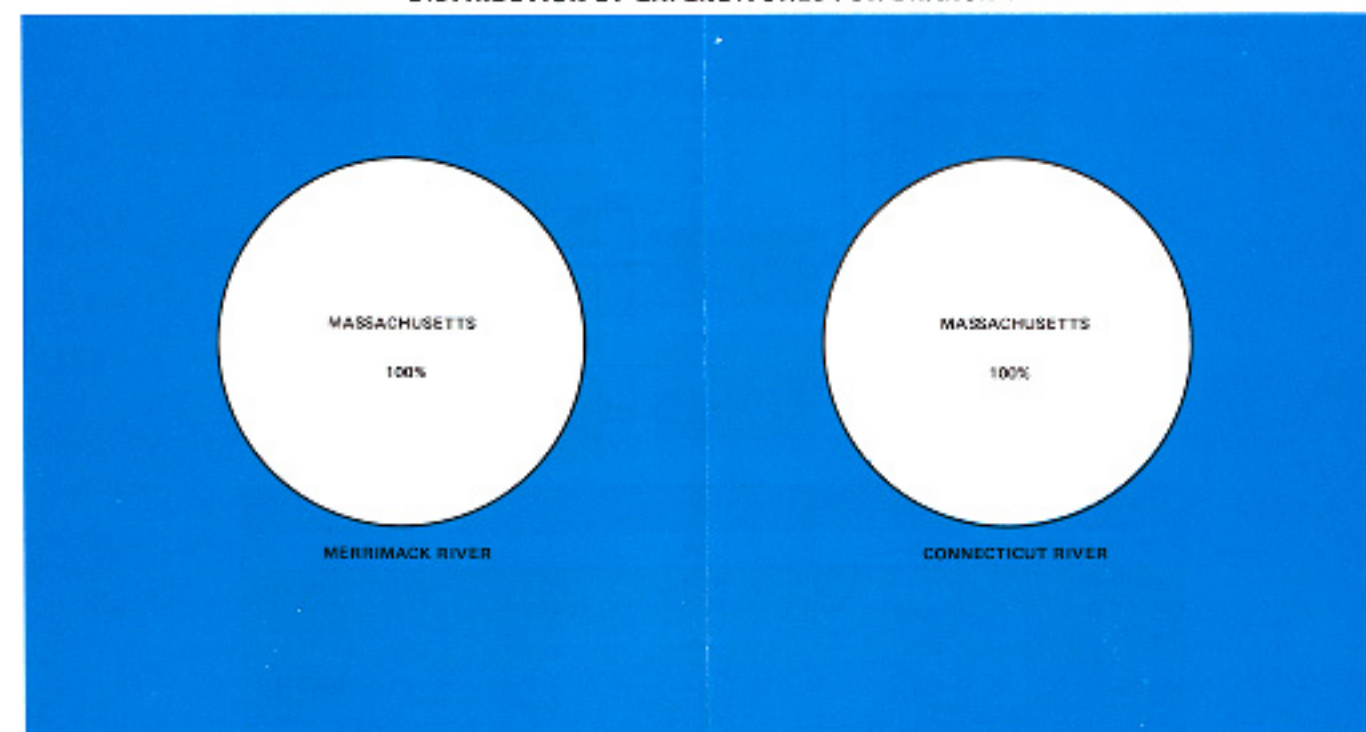
#### PROJECT DATA FOR BRANCH 1\*\*

PROJECT	ULTIMATE SAFE YD. MGD	CAPITAL COST* \$ MILLIONS	ANNUAL* OM&R \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$ MILLIONS)					
					THROUGH 1990		THROUGH 2000		THROUGH 2020	
					LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
CONN. RIVER DIVERSION	500	1183.08	14.45	200505	331.3	0	2236.3	1242.1	3437.8	2703.4
MERR. RIVER	320	740.3	8.50	98360	0	0	363.2	0	1570.8	903.2
TOTAL	820	1923.38	22.95	298865	331.3	0	2599.5	1242.1	5008.6	3606.6

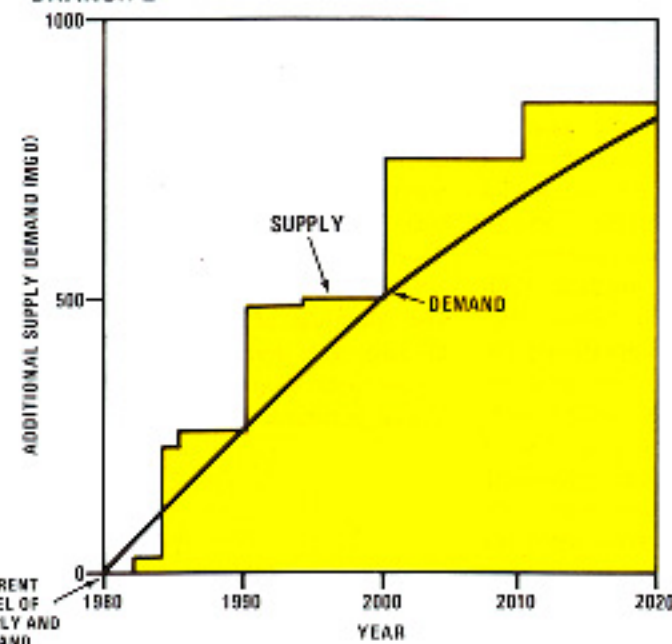
\*AT COMPLETION

\*\*ALL FIGURES IN 1974 DOLLARS

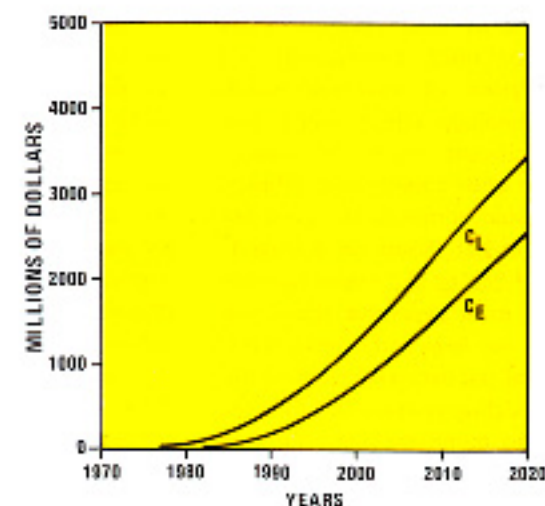
#### DISTRIBUTION OF EXPENDITURES FOR BRANCH 1



ADDITIONAL SUPPLY DEMAND VS. TIME  
BRANCH 2

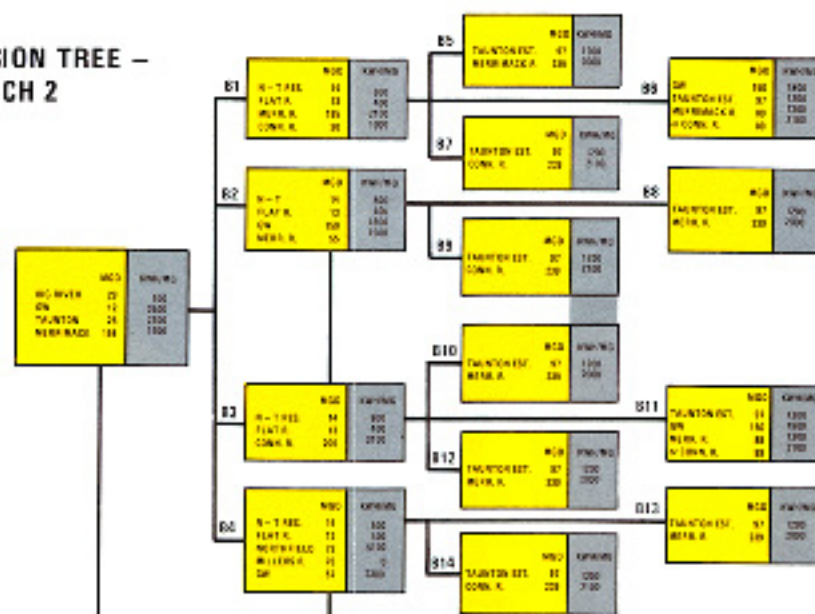


CUMULATIVE EXPENDITURES FOR BRANCH 2



$C_L$  - Local expenditures under local funding assumption  
 $C_E$  - Local expenditures under extra local funding assumption  
 Curves are approximate in shape due to scale of graph

DECISION TREE -  
BRANCH 2



YEAR	1990	2000	2020
DEMAND (MGD)	264	484	820
ADDITIONAL SUPPLY (MGD)	264	B1 - 496 B2 - 496 B3 - 496 B4 - 496	B5 - 832 B6 - 832 B7 - 832 B8 - 832 B9 - 832 B10 - 832 B11 - 832 B12 - 832
ENERGY REQUIREMENTS* KWH/MGD	1500	B1 - 1600 B2 - 1600 B3 - 1700 B4 - 1700	B5 - 1700 B6 - 1600/1700 B7 - 1700 B8 - 1600 B9 - 1600 B10 - 1700 B11 - 1600/1700 B12 - 1700

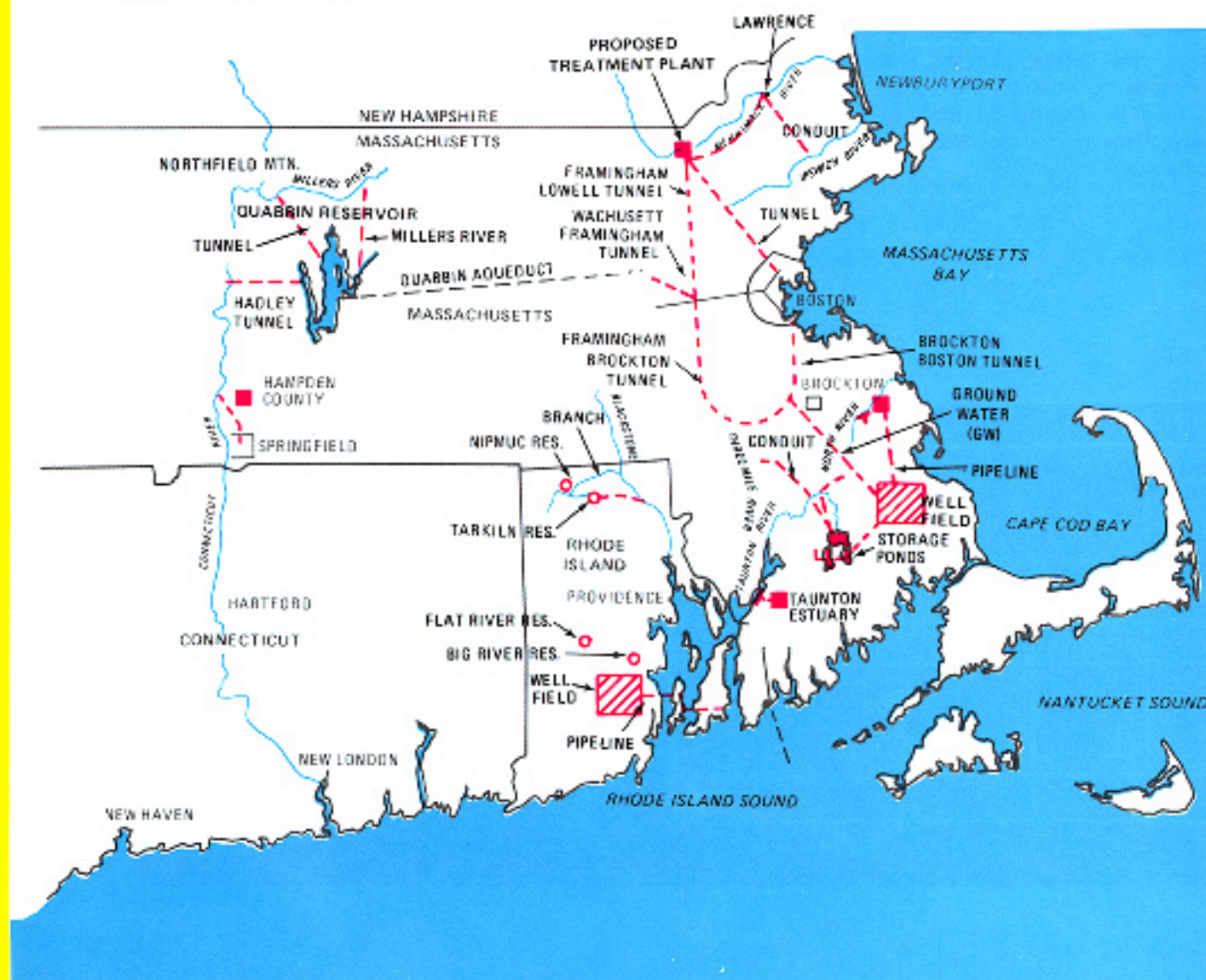
\*AVERAGE

## BRANCH 2

- REGIONAL FOCUS
- ENVIRONMENTAL QUALITY

### LEGEND:

- EXISTING STORAGE (PONDS, RESERVOIRS, ETC.)
- PROPOSED PIPELINES, TUNNELS, CONDUITS, ETC.
- EXISTING PIPELINES, TUNNELS, CONDUITS, ETC.
- PROPOSED STORAGE (PONDS, RESERVOIRS, ETC.)
- PROPOSED PUMPING STATION (OR WSP)
- PROPOSED WELL FIELDS
- ESTUARY WITHDRAWAL (RIVER VICINITY)
- WELLS
- HIGH FLOW SKIM INTERCONNECTION



**BRANCH NUMBER TWO** — A program designed to satisfy the objectives of regional focus and environmental quality, in addition to providing water supply.

#### Program Description

Three projects are proposed for the Eastern Massachusetts area for the 1980 to 1990 decade: Local groundwater would yield 12 mgd; diversion of high flows from the Taunton River with storages in existing ponds would yield 25 mgd; and diversion from the mainstem of the Merrimack River would yield 198 mgd. The total yield would be 235 mgd. Four options are described to meet the demand in the 1990 to 2000 time frame. All options would yield an additional 205 mgd. They are as follows:

1. An additional diversion of 185 mgd from the Merrimack and a diversion of 20 mgd from the Connecticut.

2. Development of a major wellfield providing 150 mgd from groundwater and diversion of 55 mgd from either the Merrimack or Connecticut.
3. A major diversion of 205 mgd from the Connecticut.
4. Groundwater development of 57 mgd and diversion from the Connecticut River Basin through the Northfield Mountain Pumped Storage Hydroelectric Project yielding 72 mgd, and diversion from the Millers River Basin yielding 76 mgd.

For the time frame from 2000-2020, Massachusetts could develop additional yield through available resources in the Connecticut and/or Merrimack River Basins, groundwater resources, and sources in the Taunton River Basin.

For Rhode Island, only the Big River project in the Pawcatuck River Basin would yield 29 mgd. For the years 1990 through 2000, Rhode Island's demand could be met with the Nipmuc River and Tarkiln Brook

development which includes a dam and reservoir on Tarkiln Brook, pumping facilities and a connecting aqueduct from the reservoir to a treatment plant. The Nipmuc would be high flow skimmed. In addition, the Flat River diversion project would put an additional 13 mgd into the Big River Reservoir.

For the period 2000 to 2020, the Taunton estuary dam and reservoir would provide 97 mgd.

#### Program Rationale

The regional focus of this program is different from that shown in Branch 1, in that water supply for the early 1980 — 1990 decade would be developed from resources near serviced areas. All of the projects would include some inter-Basin transfers; however, such transfers would be made largely within the metropolitan boundaries of the areas to be served. Thus, no import of water from outside the area is included.

With regard to environmental quality all of the projects considered in Branch 2 with the exception of the Big River Reservoir would require very little land. In the case of the Big River Reservoir, acquisition of over 8,000 acres would be necessary.

The options shown for the 1990-2000 time frame also have a regional focus. Although the State of Connecticut might object to diversions from the Connecticut, the other options in the branch provide for major groundwater development within the metropolitan area as well as increased Merrimack diversions. Within Rhode Island, development of the projects shown would serve consumers within the same broad metropolitan region in which the projects are located.

The environmental impacts for the Connecticut River diversions shown under the various options for branch 2

in the 1990-2000 time frame are expected to be minimal, based on extensive investigations of the estuary, river, and receiving storage reservoirs. The environmental impact of increased Merrimack diversions also would be minimal if they were made only during periods of high flow. The groundwater options for the 1990-2000 time frame may present environmental damages with regard to diminishment of stream flow and surface water levels located within and adjacent to the wellfield. Further study would be required to come to a more conclusive position on the environmental effect of a 150 mgd withdrawal from groundwater aquifers. The Rhode Island projects, except for Tarkiln Brook where a reservoir would be constructed, would involve flood skimming initially. Ultimately, a reservoir may be needed on Nipmuc River, but this would depend on water needs at the time.

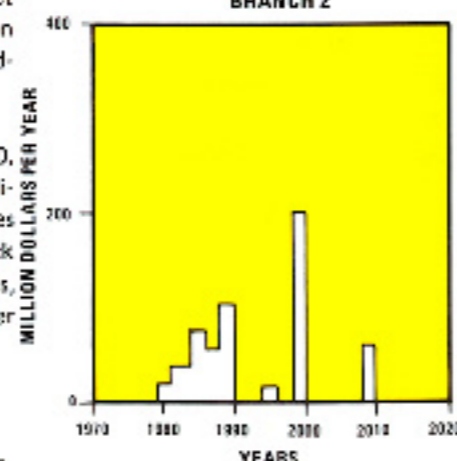
**PROJECT DATA FOR BRANCH 2\*\***

PROJECT	ULTIMATE SAFE YD. MGD	CAPITAL COST* \$ MILLIONS	ANNUAL OM&R \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$ MILLIONS)					
					THROUGH 1990		THROUGH 2000		THROUGH 2020	
					LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
BIG RIVER	29	56.2	1.27	114	7.9	0	110.6	77.0	187.4	150.1
GROUND WATER	12	27.0	1.10	1255	0	0	38.6	26.3	98.5	75.6
TAUNTON	25	51.0	1.52	11309	0	0	82.3	64.3	179.9	145.7
MERRIMACK RIV.	198	245.0	6.20	25956	68.7	0	519.4	313.5	834.3	682.2
N - T RESERVOIR	14	29.8	.53	2380	0	0	24.6	14.1	77.0	54.3
FLAT RIVER	13	10.4	.58	910	0	0	3.6	1.1	29.7	23.0
GROUND WATER	150	183.2	6.56	11156	0	0	252.1	172.0	640.3	484.8
MERRIMACK RIV.	55	47.5	1.41	6830	0	0	82.1	41.4	157.1	116.6
TAUNTON EST.	97	120.5	4.58	4680	0	0	0	0	155.7	115.8
MERRIMACK RIV.	239	556.0	7.45	23907	0	0	163.1	34.9	1090.3	734.0
<b>TOTAL</b>	<b>832</b>	<b>1325.7</b>	<b>31.30</b>	<b>88497</b>	<b>76.6</b>	<b>0</b>	<b>1266.6</b>	<b>745.6</b>	<b>3450.2</b>	<b>2990.1</b>

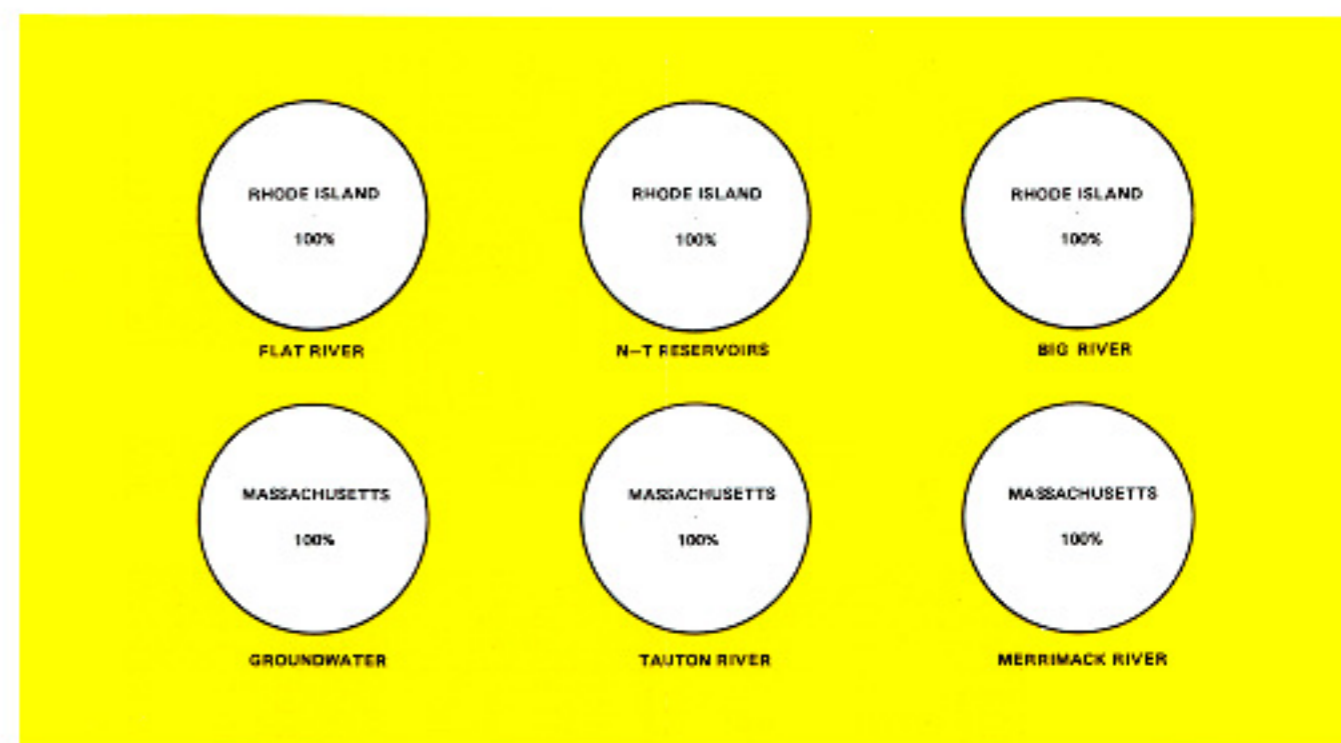
\* AT COMPLETION

\*\* ALL FIGURES IN 1974 DOLLARS

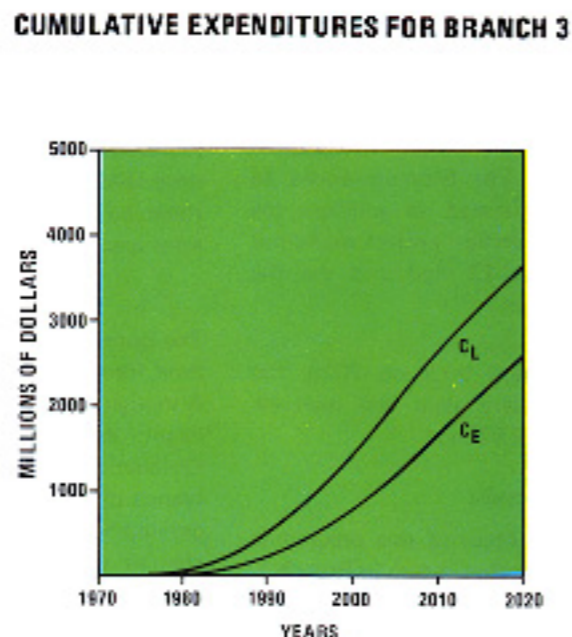
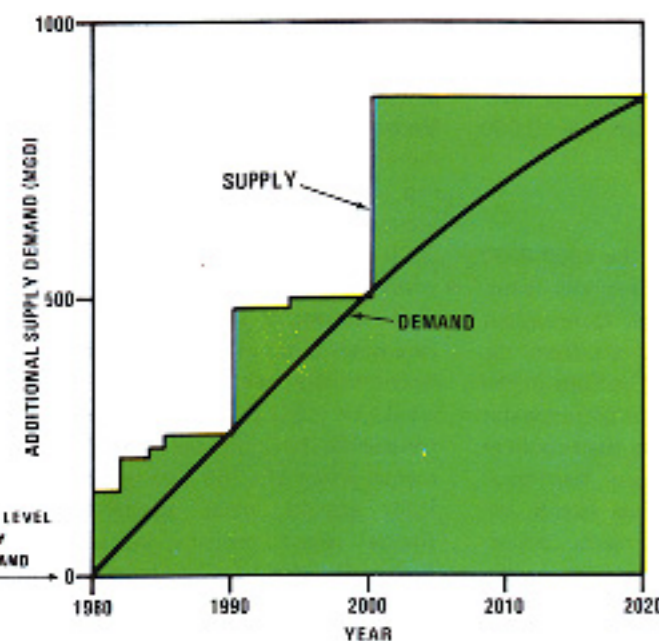
**CAPITAL REQUIREMENTS  
BRANCH 2**



**DISTRIBUTION OF EXPENDITURES FOR BRANCH 2**

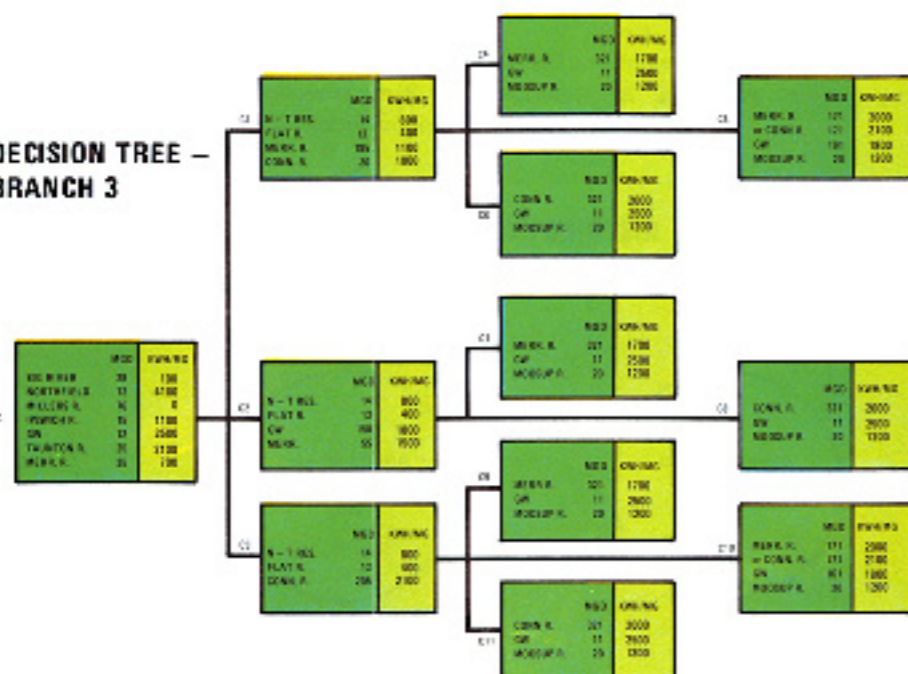


# ADDITIONAL SUPPLY DEMAND VS. TIME BRANCH 3



C<sub>L</sub> - Local expenditures under local funding assumption  
C<sub>E</sub> - Local expenditures under extra local funding assumption  
Curves are approximate in shape due to scale of graph

## DECISION TREE - BRANCH 3



YEAR	1990	2000	2020
ADDITIONAL DEMAND (MGD)	264	484	320
ADDITIONAL SUPPLY (MGD)	264	C1 - 496 C2 - 496 C3 - 496	C4 - 848 C5 - 848 C6 - 848 C7 - 848 C8 - 848 C9 - 848 C10 - 848 C11 - 848
ENERGY REQUIREMENTS* KWH/MG	1600	C1 - 1300 C2 - 1600 C3 - 1700 C4 - 1500	C5 - 1900 C6 - 1600 C7 - 1900 C8 - 1800 C9 - 1700 C10 - 1800 C11 - 1800

\*AVERAGE

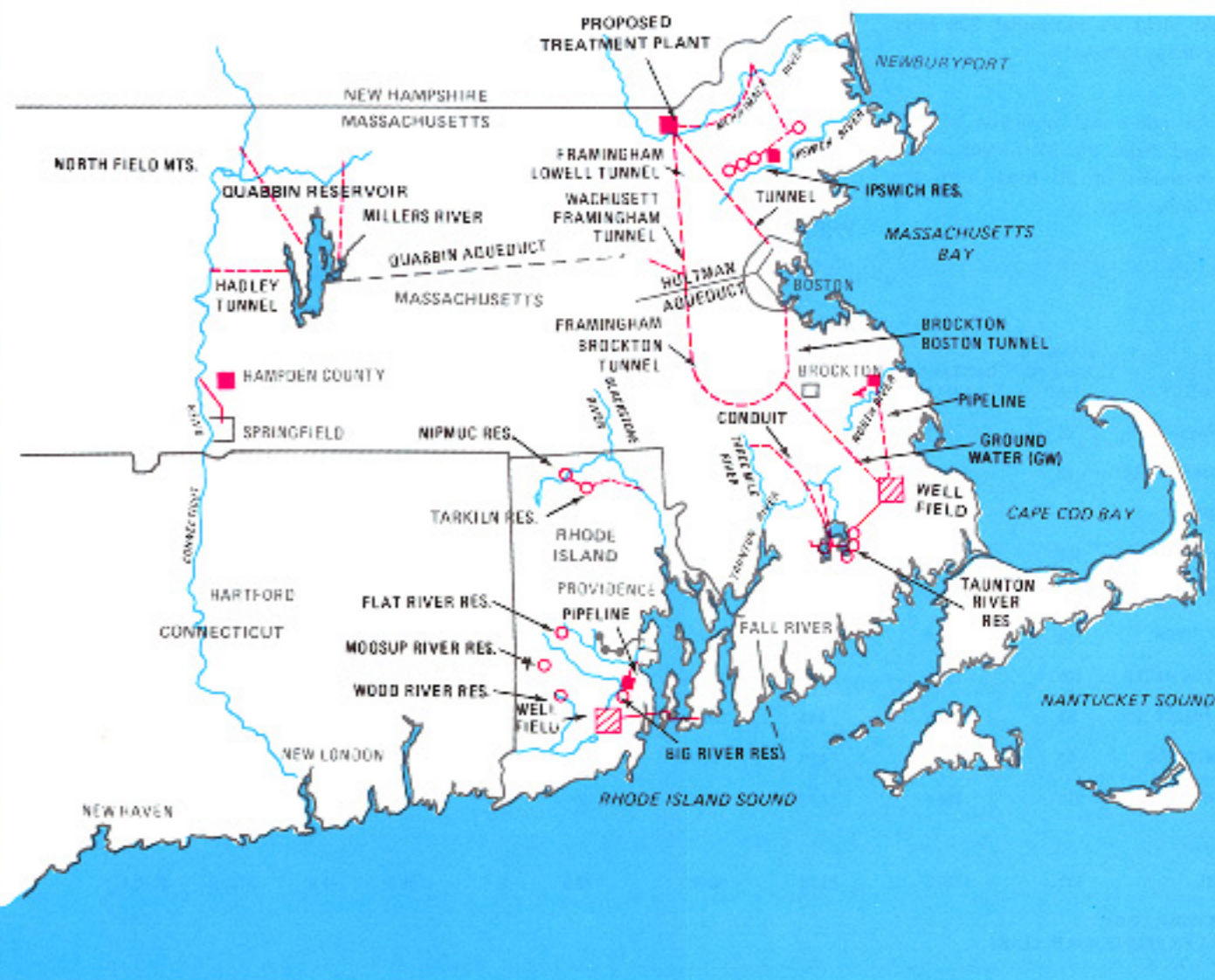
## BRANCH 3

- RELIABILITY
- REGIONAL FOCUS

- COST
- FLEXIBILITY
- ENVIRONMENTAL QUALITY

### LEGEND:

- EXISTING STORAGE (PONDS, RESERVOIRS, ETC.)
- PROPOSED PIPELINES, TUNNELS, CONDUITS, ETC.
- EXISTING PIPELINES, TUNNELS, CONDUITS, ETC.
- PROPOSED STORAGE (PONDS, RESERVOIRS, ETC.)
- PROPOSED PUMPING STATION (ON WSP)
- PROPOSED WELL FIELDS
- ESTUARY WITHDRAWAL (RIVER MIXITP)
- WELLS
- HIGH FLOW SKIM INTERCONNECTION



**BRANCH NUMBER THREE** — A program designed to satisfy the objectives of reliability, regional focus, cost, flexibility, and environmental quality, as well as providing water supply.

The Branch 3 program partially satisfies all of the major objectives mentioned in discussions with area officials.

#### Program Description

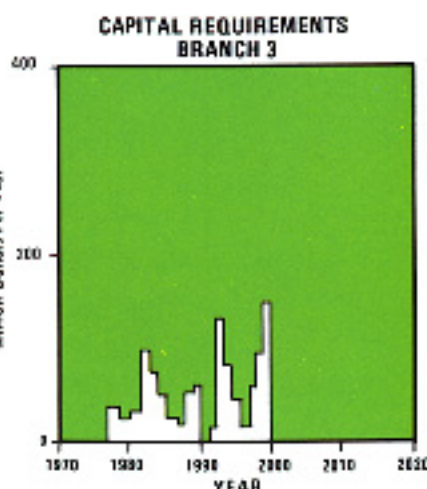
For the Massachusetts area, this branch consists of six projects with a total yield of 235 mgd for the 1980-1990 decade. The projects are: pumped storage from Northfield Mountain providing 72 mgd; diversions from the Millers River for 76 mgd;

diversions from the Ipswich River for storage in off-stream reservoirs providing 15 mgd; groundwater yielding 12 mgd; high flow diversion from the Taunton River into existing reservoirs providing 25 mgd; and withdrawals from the Merrimack yielding 35 mgd.

For Rhode Island in the same decade, the Big River project would yield 29 mgd.

The 1990-2000 demands in the Massachusetts area would be met by diversions of 185 mgd from the Merrimack and 20 mgd from the Connecticut; or 205 mgd from the Connecticut; or 150 mgd from groundwater coupled with diversions of 55 mgd from either the Merrimack or the Connecticut.

Rhode Island would meet its additional demands with development of the Nipmuc and Tarkiln Reservoir project for 14 mgd and the Flat River Reservoir which would provide 13 mgd.



**PROJECT DATA FOR BRANCH 3\*\***

PROJECT	ULTIMATE SAFE YD. MGD	CAPITAL COST* \$ MILLIONS	ANNUAL* OM&R \$ MILLIONS	CONNECTED* LOAD (KW)	LOCAL EXPENDITURES (\$ MILLIONS)					
					THROUGH 1990		THROUGH 2000		THROUGH 2020	
					LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING	LOCAL FUNDING	EXTRA LOCAL FUNDING
BIG RIVER	29	56.20	1.27	114	7.9	0	110.3	77.0	187.4	158.1
NORTH FIELD	72	50.90	.91	63090	19.7	6.9	189.2	75.5	163.1	144.1
MILLERS RIVER	76	53.40	1.03	0	20.3	7.4	116.3	80.9	174.3	154.4
IPSWICH RIVER	15	32.00	1.23	2732	0	0	85.8	47.9	124.0	104.2
GROUND WATER	12	27.00	1.10	1256	0	0	38.5	26.8	98.5	75.5
TAUNTON RIVER	25	74.85	1.84	11310	0	0	129.2	88.8	249.9	199.7
MERR. RIVER	35	33.27	.99	1027	4.7	0	70.1	50.1	120.3	102.9
N - T RESERVOIR	14	28.00	.53	2380	0	0	24.5	14.1	77.0	54.3
FLAT RIVER	13	10.40	.58	910	0	0	3.5	1.1	29.7	23.0
MERRIMACK	185	248.00	6.00	17334	0	0	368.0	196.8	825.5	554.5
CONN. RIVER	20	24.80	1.22	799	0	0	31.6	27.0	97.0	76.0
MERRIMACK	321	628.00	10.85	26013	0	0	347.8	41.8	1436.2	873.0
GROUNDWATER	11	8.60	.46	1145	0	0	2.9	0.9	24.5	18.9
MOOSUP RIVER	20	24.30	1.11	4098	0	0	7.3	2.3	64.1	48.5
<b>TOTAL</b>	<b>648</b>	<b>1285.72</b>	<b>29.12</b>	<b>133678</b>	<b>53.1</b>	<b>14.3</b>	<b>1433.4</b>	<b>730.8</b>	<b>3671.5</b>	<b>2687.3</b>

\* AT COMPLETION

\*\* ALL FIGURES IN 1974 DOLLARS

Massachusetts would meet the additional demand in the 2000-2020 period with a combination of projects including a groundwater development and major diversions from the Connecticut and/or Merrimack Rivers. Rhode Island, meanwhile, would meet its additional demands with development of groundwater resources, and construction of the Moosup Reservoir.

#### Program Rationale

Branch 3 offers a program insuring reliability of supply. The possibility of not having sufficient quantities of water to meet future demands is lessened by the availability of the various sources tapped. During the 1960's drought, for example, several river basins within New England suffered extremely low runoff conditions while other basins escaped these most severe conditions. Branch 3 would develop a number of basins and thus provide a

safeguard against the drought which does not affect all basins with equal severity.

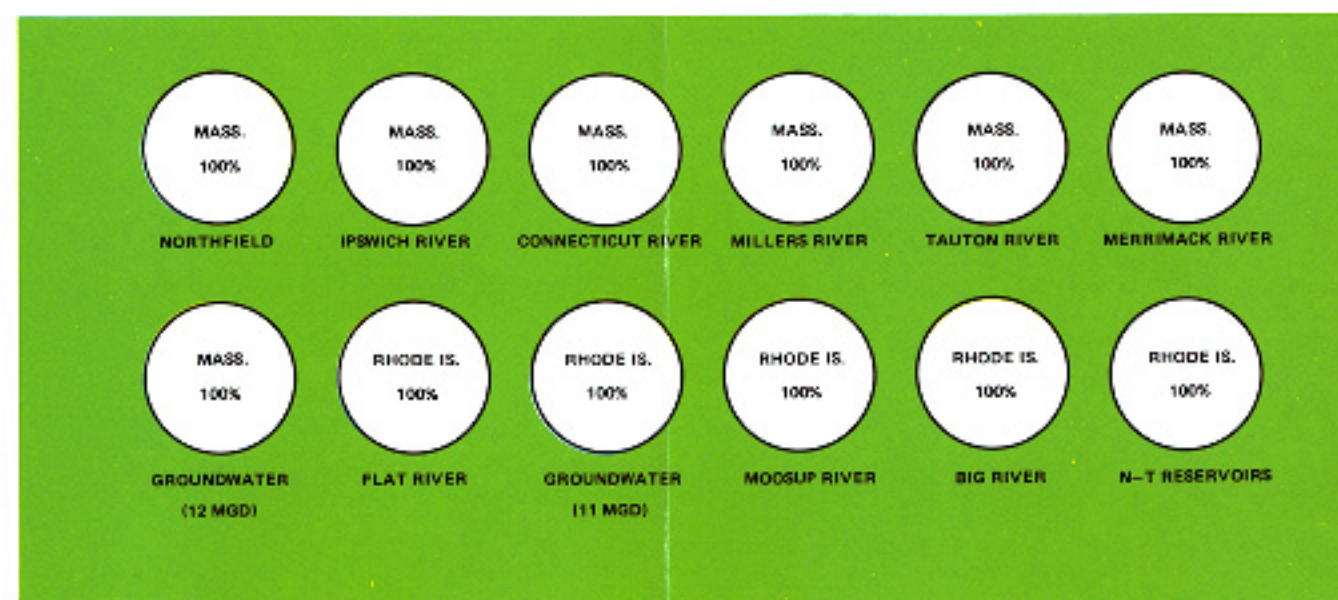
With regard to cost, branch 3 is a low cost program in terms of both capital and operating expenditures because many of the projects use existing storage and transmission facilities. In addition, these projects do not require a large irreversible investment early in the planning period.

It also offers a program which minimizes the concerns of regional focus since a number of the projects proposed will meet water supply demands in that section of the area in which they are located. This is accomplished primarily in the 1980-1990 years. Regional focus, as it relates to the 1990-2000 decade, is much the same as noted for branch 2.

During the 1980-1990 years, this branch offers a great degree of flexibility. Individual projects can be implemented as discreet modules in an overall regional system. Thus, acceptable projects can proceed independently of another project which may prove difficult to implement. The flexibility inherent in branch 3 is continued in the 1990-2000 decade because the option relies on groundwater development which can be constructed as needed.

Negative environmental impact for the early years of branch 3 appears minimal since no one river will experience any substantial diversions, and most projects require little land taking. From 1990-2000, environmental impacts would be similar to those expected with branch 2.

#### DISTRIBUTION OF EXPENDITURES FOR BRANCH 3



## ANNOTATED BIBLIOGRAPHY

### I OVERALL STUDIES

*Plan of Study for Northeastern United States Water Supply*, Corps of Engineers, North Atlantic Division, September, 1966. A general overview of the NEWS Study is presented, including a background discussion of the area, short and long range objectives, and a discussion of the relation between the News Study and similar activities of the States and other Federal Agencies.

*1966 Water Drought Restrictions*, Public Service Research, 1967. Presents an inventory of the water use restrictions which were placed in effect during the 1966 drought.

*Water Utility Lists, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Washington, D.C., Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia*, Public Service Research, 1967. Basic data is provided on all water supply companies in the NEWS Area, including population served, quantity produced, and gross water revenue.

*Water Utility Directory*, Public Service Research, September, 1968. The directory lists by state all water utilities including county location, size, classification, source of water, and nature of ownership.

*Municipal Financing of Water Projects for Northern New Jersey*, Sanford L. Bordman, January, 1969. Case study of the financial aspects of investments for water supply systems for the municipalities of Northern New Jersey.

*Anticipated and Emerging Advances in Water Supply Technology*, International Research & Technology Corporation, February, 1972. Studies anticipated and emerging major advances in water supply technology, including advanced water treatment of polluted, brackish and otherwise unusable sources, desalination, weather modification and iceberg harvesting.

*Preliminary Study of Long Range Water Supply Problems of Selected Urban Metropolitan Areas*

Volume I Main Report

Volume II Area Reports

Anderson—Nichols & Co., Inc., November, 1973. Examines 26 urban metropolitan areas throughout the Northeast and identifies the areas which may experience major regional municipal, domestic and industrial water supply problems. The report also investigates opportunities to provide these areas with adequate water supply through the year 2020.

### II WASHINGTON METROPOLITAN STUDY AREA (WMA)

*Potomac Estuary Water Supply: The Consideration of Viruses*, Environmental Protection Agency, March, 1973. This study provides the results of laboratory experiments on the differences in resistance to chlorination of twenty-five strains of human intestinal viruses that were suspended in estuary water. Conclusions are drawn from this work from a public health viewpoint as to the feasibility of using the Potomac Estuary as a supplemental source of water for the Washington Metropolitan Area. This was a companion study to the "Potomac Estuary Water Supply: its feasibility as a supplementary source."

*Potomac River Basin Water Supply, An Interim Report*, Corps of Engineers, North Atlantic Division, Baltimore District, April, 1973. This Report is a response to the 1972 Conference Report on S. 4018, "Public Works on Rivers and Harbors," to reformulate the Sixes Bridges and Verona Dam and Lake projects for purposes other than low flow augmentation for water quality. The Report evaluates water supply problems in the Potomac River Basin with special emphasis on the Washington Metropolitan Area. It integrates the Two Projects into an overall long-term water supply program for the WMA, recommends that a prototype advance water treatment plant be Federally authorized and constructed, and thus served as an interim report on the ongoing studies in the WMA under the Northeastern United States Water Supply Study (Title I, PL 89-298).

*Metropolitan Washington Area-Special Water Supply Study*, Tetra Tech, Inc., July, 1973. This study provided services and work elements necessary to determine the impact of non-point pollution on water supplies; to review, evaluate, and update information on present water resources and supply systems in the WMA; and to prepare a base-line environmental analysis of the study area with specific emphasis on water supply. This effort was limited to collection, review, and interpretation of the existing information.

*Potomac Estuary Water Supply: Its Feasibility as a Supplemental Source*, Hydrosience, Inc., August, 1973. This study examines the potential for meeting drinking water standards with Potomac Estuary water treated by known techniques. The study employed a steady-state water quality model of the estuary to determine what the quality of treated estuary water would be under various conditions of river flow and water demand.

*Potomac Estuary Water Supply: Architectural and Urban Design Considerations*, Paul D. Spreiregen, August, 1973. This report is a graphical essay in site layout and architectural design criteria for the proposed one mgd pilot estuary water treatment facility.

*Growth and Water Supply in the Washington SMSA*, Development Sciences Inc., January, 1974. This report analyzes the magnitude and distribution of population growth and its relationship to water supply in the WMA. The study first examines how well-water supply devices alone could aid in the control of population growth and second, it takes a broader look at the problem of growth control by taking an inventory and examining all growth control mechanisms then being studied by each county in the Washington Standard Metropolitan Statistical Area (SMSA).

*Open Planning and Decision Mapping as the Basis for a Water Supply Plan*, Development Sciences, Inc., January, 1974. This study develops and utilizes an integrated approach to decision mapping and open planning for water supply in the WMA. Decision mapping was used to identify major issues, groups and agencies concerned with water supply in the area. Open planning was used along with decision mapping to insure that the public's interests and concerns were addressed and incorporated in each phase of the Corps' planning.

*An Open Planning Methodology for Evaluation of Water Supply Devices in the Washington, D.C. SMSA*. Development Sciences, Inc., January, 1974. A methodology is presented to evaluate water supply devices and programs by including traditional engineering data and a range of social, political and environmental data that describes the acceptability of the devices and programs. The method is designed to use the values of the Washington Metropolitan community and its officials as identified through the open planning process. The method also lends itself to use as an educational tool for both the planner and the Washington community when used as an aid in open planning meetings. The report identifies the type of data needed, where the data may be obtained and examples of applications of the evaluation method.

*Preliminary Institutional Arrangements for Water Supply in the Washington Area*, Development Sciences, Inc., January, 1974. This report presents the existing institutional framework as background to aid in the understanding of how various Corps programs for water supply would fare in the present institutional setting of the Metropolitan Washington area. The report delineates the institutional, legal and funding problems that would be faced during implementation of alternative water supply programs studied by the WMA Study group. Suggestions are made on how the alternative programs could be modified to make them politically feasible.

*A Staff Report on Alternative Water Supply Programs for the Metropolitan Washington Area*, Corps of Engineers, North Atlantic Division, April, 1974. This report displays the planning process and initial results for the WMA water supply study as part of the NEWS Study. So that feedback could be obtained on the study from interested publics and agencies, the report contains descriptions of preliminary water supply projects and programs and the major assumptions, rationale and procedures used to derive them. Preliminary conclusions were made.

*Socio-Economic Impact Study of Alternative Water Supply Systems for the Metropolitan Washington, D.C. Area*, Arthur D. Little, Inc., November, 1974. This report presents the socio-economic impacts of possible water supply alternatives considered for the Metropolitan Washington Area (MWA). Baseline socio-economic data is given for the entire MWA and for each county and the District of Columbia. This baseline data provides a point of reference from which the impacts of 13 projects and 5 basin programs are measured.

*Potomac Estuary Water Supply: A Prototype Water Treatment Facility*, Hydrosience, Inc., December, 1974. This report was the basis of a Corps proposal to construct and operate a one mgd pilot estuary water treatment facility (now authorized). Based on the results of operating a time-variable water quality model, it was concluded that the Potomac Estuary appears to be suitable as a permanent regional source of water, but due to potential health hazards, extensive testing would be required. Operation of the proposed prototype facility would provide the detailed information needed to evaluate this approach to water supply. The report also presents a design for the pilot facility and site selection criteria for both a pilot and regional facility.

*Effects of Water Supply Deficits, Washington Metropolitan Area*. Water Resources Engineers, January, 1975. A study to define procedures for estimating losses for future water supply shortages that would affect domestic, commercial, governmental and industrial water users in the WMA. Also determines the probable short term economic losses and probable aggregate effects of intermittent water shortages over the water supply and distribution systems of the WMA.

*Simulation Model for the Metropolitan Washington Area Water Supply System*, Vol I & II, Meta Systems, Inc., April, 1975. A model was developed to allow the examination of the interconnected aspects of the WMA Water Supply system and the possibility of using various combinations of devices and operating procedures to meet both short and long term water supply requirements. The model is descriptive rather than predictive in that it describes the consequences of decisions made rather than indicating what decision is to be made. The model was structured to develop a system configuration which satisfies demands for the multiple demand centers of the system.

*Engineering Feasibility of Alternative Water Supply Projects for the Metropolitan Washington Area*, Engineering-Sciences, Inc., May, 1975. This Study provides an adequate level of engineering design and cost data for the formulated alternative water supply programs. This data provides a quantitative and qualitative basis for narrowing down the range of choices to implementable and feasible water supply projects.

*Environmental Impact of Alternative Water Supply Programs and Projects for the Washington Metropolitan Area*, WAPORA, Inc., September, 1975. Provides environmental data and projected impact assessments of alternative water supply projects and programs for the WMA. Using data collected these water management projects and programs are compared and impacts are assessed on geographic units ranging from the regional to the immediate project area.

### III NEW YORK METROPOLITAN STUDY AREA (NYMA)

*Surface Water Supply Capabilities of Northern New Jersey River Basins*, Quirk, Lawler and Matusky Engineers, December, 1968. The objective of this study was to obtain firm yields, for various drought occurrences, of the surface water supply systems within the Hackensack, Raritan, Passaic, Navesink, and Shark River Basins.

*Engineering Feasibility Report on Alternative Regional Water Supply Plans for the Northern New Jersey—New York City—Western Connecticut Metropolitan Area*, Metcalf & Eddy—Hazen & Sawyer, November, 1971. This investigation was performed to develop feasible engineering alternatives for water supply systems to meet the domestic and industrial water needs of the study area to the year 2020.

*Organizational, Legal, and Public Finance Aspects of Regional Water Supply*, Institute of Public Administration, July, 1972. This report investigated the legal, institutional and economic issues involved in regionalization of public water supply in the New York and southeast New England NEWS Study Area, and presented alternative general institutional frameworks for regional water supply management.

*Effect on the Environment of Regional Water Supply Alternatives for the Northern New Jersey—New York City—Western Connecticut Metropolitan Area*, The Center For The Environment and Man, Inc., November, 1972. This report contains an overview and preliminary analysis of probable environmental impacts for the fourteen projects used to develop the seven regional programs described in the Joint Venture report, assuming maximum development of facilities for water supply (which would not necessarily be the case). The report describes qualitative rather than quantitative impacts and does not attempt to rank projects by their impacts.

*Evaluation of Alternative NEWS Water Supply Systems for the Northern New Jersey—New York City—Western Connecticut Metropolitan Area*, Linton, Miels and Coston, Inc., June, 1973. The purpose of this study was to develop an impact assessment and multi-objective evaluation framework, with the attendant plan formulation process, and to apply this framework on the local case study and regional levels to the seven illustrative regional programs for the New York Study Area developed in the Joint Venture report.

In three volumes:

**Volume I:** Introduction and Summary Findings. An overall summary of the study's techniques and findings on both the local case study and regional levels.

**Volume II:** Case Study Evaluation. Contains the case study methodology and individual case studies for each of ten projects.

**Volume III:** Regional Evaluation. Presents the methodology and findings for the regional analysis of seven illustrative programs.

*Further Development of Regional Water Supply Development Alternatives for Northern New Jersey—New York City—Western Connecticut Metropolitan Area*, Parson, Brinckerhoff, Quade and Douglas, Inc., June, 1973. The objective of this study was to develop additional project alternatives and illustrative regional programs for water supply work in the New York Metropolitan Study Area, supplementary to the work in the Joint Venture study, and to prepare a computer programming algorithm to serve as a tool for analysis of additional regional programs by the contracting agency.

*Legal, Institutional and Cost-Sharing Requirements for Implementing Water Supply Projects in the Northern New Jersey—New York City—Western Connecticut Metropolitan Area*, Booz Allen Public Administration Services, Inc., June, 1973. The purpose of this study was to further examine the legal, institutional, and cost-sharing requirements for the implementation of both individual projects and regional programs of projects for water supply in the New York Study Area.

*Water Supply: Wastewater Management Aspects for the Northern New Jersey—New York City—Western Connecticut Metropolitan Area*, Nebolsine, Toth, McPhee Associates, June, 1973. The objective of this study was to perform a survey of the existing legislation, programs, water quality and future quality conditions of water sources in the study area and the Delaware, Hudson and Housatonic River Basins, and to examine programs to protect or enhance quality of alternative water supply sources which may be utilized to meet the projected needs of the New York Metropolitan Study Area. This work was developed at a low level of detail, utilizing existing data.

*An Opportunity for the Future: Integrated Water Supply—Power Generation—Wastewater Management—Land Control*, Quirk, Lawler and Matusky Engineers, December, 1973. The objective of this study was to evaluate the feasibility of implementing a wastewater—total resource management program for Long Island, New York, which would eventually combine a nuclear power plant, a waste treatment facility and a land application system and/or other methods of waste heat utilization for the overall purpose of system efficiency and improvement of water supply management on Long Island.

*Institutional Issues Surrounding a Hudson River Diversion to New Jersey*, Dunka, Gaston and Westwater, Inc., August, 1974. This report discusses the legal, institutional and financial problems likely to occur if Hudson River Water from New York State is diverted to New Jersey as part of a regional water supply program.

*Summary—Hudson River Hydrology Study*, Quirk, Lawler and Matusky Engineers, August, 1974. A concise summary of the full 500 page report. This summary provides an analysis of the firm yields available for water supply in the Hyde Park-West Park area for several alternative operating schemes of existing and considered reservoirs in the Hudson River Basin.

*Hydraulic Analysis of the New York City Water Supply System*, Quirk, Lawler and Matusky Engineers, September, 1974. The study provides an analysis of the delivery portions of the City's water supply system from the sources to the head of the local distribution system.

*Report on the Interconnection and Safe Yields of the Major Water Utilities in Northern New Jersey*, Dr. Robert M. Hordon, Consultant, September, 1974. This study provides an inventory of all interconnections that exist for the eleven major water utilities in northern New Jersey. The report also examines the safe yields and annual average diversions for each utility.

*Water Demand Projections and Sensitivity Analysis for the New York Metropolitan Area*, INTASA, Inc., September, 1974. This report describes the methodology used to develop projections of future water demand for the NYMA. The report also analyzes the sensitivity of these projections to be altered assumptions about underlying conditions, such as population, economic activity, land use and community development, and basic water consumption practices.

*Water Management Alternatives on Long Island*, Environmental Technology Seminar, Inc., October, 1974. As part of the open planning effort the New York Metropolitan Area (NYMA) Study has purchased several copies of this report and is making copies available. The report is a handbook of relevant information on the water management problems on Long Island. A detailed summary of the report is also available.

*Analysis of Regional Water Supply Programs for the Northern New Jersey—New York City—Western Connecticut Metropolitan Area*, Linton & Co., June, 1975. This study further develops, extends and applies the analytical techniques for impact assessment and multi-objective evaluation originally developed in *Evaluation of Alternative NEWS Water Supply Systems*. Greater emphasis is placed on analysis of environmental, social and institutional impacts than in the earlier study, and assessment is made of short-run construction impacts, system reliability, and system flexibility. The expanded methodologies are applied to selected projects and programs.

*Demonstration Project for Total Resource Management*, Quirk, Lawler & Matusky Engineers, (ongoing study). This is a survey-scope level study for a demonstration project to develop operating experience and resolve technical uncertainties in total resource management. This effort, an extension of the study *An Opportunity for the Future: Integrated Water Supply—Power Generation—Wastewater Management—Land Control*, was conducted jointly by NYMA Study and the New York State Atomic and Space Development Authority. Other Federal, State and Local agencies have also contributed to the planning and design of the project.

#### IV EASTERN MASSACHUSETTS—RHODE ISLAND METROPOLITAN AREA

##### 1 WATER SUPPLY REPORTS:

**INTERIM MEMORANDA** These eight limited detailed studies were intended to present an overview of the water supply situation for some of the larger metropolitan areas within New England.

*Interim Memorandum No. 1 — New Bedford, Fall River and Taunton*, Corps of Engineers, New England Division, April, 1968. This Tri-City area in southeastern Massachusetts was analyzed to evaluate its future water supply outlook. The population, water supply and water demand were discussed and projections made for the population and water demand through the year 2020. Possible sources of water adequate for a regional supply were examined and discussed.

*Interim Memorandum No. 2 — Springfield—Chicopee—Holyoke Area*, Corps of Engineers, New England Division, April, 1968. The Springfield—Chicopee—Holyoke region in western Massachusetts was examined for its capability to meet future water supplies. Present and future population and water demand figures through the year 2020 were presented. Adequacy of the region's three major systems was investigated and apparent urgent and future needs were discussed and possible courses of action were described.

*Interim Memorandum No. 3 — Bridgeport—New Haven subregion*, Corps of Engineers, New England Division, July, 1968. The Bridgeport—New Haven, Connecticut area was investigated to determine future potential water supply deficits. Present and future population and water demand requirements were presented through the year 2020. Adequacy of the major water systems was studied and apparent urgent and future needs were discussed. Potential regionwide supply sources were examined and described.

*Interim Memorandum No. 4 — Southern New Hampshire Tri-City area*, Corps of Engineers, New England Division, August, 1968. The Concord—Manchester—Nashua area of New Hampshire was investigated to determine future water supply needs. Present and future population and water demands through the year 2020 were presented. Sources of water which could be developed to meet the needs through 2020 were examined and described.

*Interim Memorandum No. 5 — Worcester—Boston*, Corps of Engineers, New England Division, September, 1968. The Metropolitan District Commission (MDC) system, the major supplier in the Worcester—Boston area, was investigated in this

memo considering only the then existing system service area. The present and projected population and water demands through the year 2020 and the capability of the system to meet these needs was described.

*Interim Memorandum No. 6 — Metropolitan Boston Area*, Corps of Engineers, New England Division, September, 1968. This memorandum builds on Memo No. 5 in that it examined the implications of the addition of future suburban customers to the MDC system.

*Interim Memorandum No. 7 — Worcester—Boston*, Corps of Engineers, New England Division, September, 1968. Five sub-regions within the Worcester—Boston region but not included in the primary service area of the MDC were discussed in this report. These sub-regions — City of Fitchburg, City of Worcester, Ipswich River Watershed District, Upper Charles River Basin Communities, and the Central Plymouth County Water District — were examined for their capability in meeting future water demands through the year 2020.

*Interim Memorandum No. 8 — Rhode Island*, Corps of Engineers, New England Division, October, 1968. Future water supply needs within the State of Rhode Island were examined. Present and future population and water demand figures through the year 2020 were presented and possible supply sources were described.

*St. Lawrence River Diversion*, Corps of Engineers, New England Division, October, 1968. This report studied the potential of utilizing the St. Lawrence River as the source for meeting the future water supply requirements of the Northeastern United States as projected through the year 2020. Two plans and preliminary cost estimates for conveying water supply to major users are included in the report. The study indicates general scope of the engineering and economic feasibility of this diversion.

*Draft — Feasibility Report on Alternative Regional Water Supply Plans for Southeastern New England*, Corps of Engineers, New England Division, November, 1969. The objective of this report was to formulate engineering alternatives for a regional water supply system to meet future needs within southeastern New England. As described in the report, these engineering alternatives were formulated without regard to the "institutional restraints — legal, economic, or organizational — which might inhibit regionalization of water supply."

*Ecological Study Merrimack River Estuary—Massachusetts*, Normandeau Associates, Inc., November, 1971. This study was designed to determine the potential environmental effects of diversion of water from the Merrimack River in the vicinity of Lowell, Massachusetts, and to give a qualitative evaluation of the significance of these effects on the ecology of the estuary and associated wetlands.

*Possible Effects of Various Diversions from the Connecticut River*, Essex Marine Laboratory, May, 1972. This study reports on efforts to predict the probable impact of upstream freshwater diversion during freshet periods on the salinity — temperature regimen of the Connecticut River estuary and to further correlate these changes with possible effects on the biotic community of the estuary.

*Identification and Assessment of Socio-Economic Impacts on the Connecticut and Millers River Basin Diversions*, Abt Associates, Inc., June, 1972. This report describes investigations which identify changes attendant on the Northfield Mountain and Millers River Basin water supply projects that will affect human population in the immediate supply area and among potential receivers. Changes are quantified and characterized where possible in terms of magnitude, direction and duration.

*Water Quality Studies, Connecticut and Millers River Systems and Quabbin and Wachusett Reservoirs, Massachusetts*, New England Research, Inc., June, 1972. This report describes studies on the probable effects of diversion of flow from the Connecticut and Millers River Basins and their possible effects on the Quabbin and Wachusett Reservoirs.

*Site Preservation for Water Resources Projects. A Legal, Economic and Institutional Analysis*, Curran Associates, Inc., January, 1973. This study examined methods historically employed to assure tracts of land will be available for future water resources development; the success of these methods and an evaluation of each of these methods as they pertain to New England. Efforts by the State of Rhode Island in acquiring reservoir site preservation are used as a case study by the report.

*Millers River Basin Water Supply Project*, Corps of Engineers, New England Division, October, 1974. This study reports investigations into methods of augmenting water supply sources for a number of communities in the eastern Massachusetts region. Population and water demand figures both present and projected are discussed and alternative methods of meeting future supply means are described. The report recommended development of water resources in the Millers River Basin via facilities which would divert high flows from the Millers Basin to Quabbin Reservoir.

*Northfield Mountain Water Supply Project*, Corps of Engineers, New England Division, October, 1974. This study which is a companion of the Millers River Basin project report recommended the development of a high flow skimming operation which utilizes the existing pumped storage hydroelectric facility at Northfield Mountain and diverts flow to Quabbin Reservoir.

*Water Demand Study, Eastern Massachusetts Region*, Coffin and Richardson, Inc., November, 1974. This study investigated existing patterns of municipal water use for domestic, commercial, industrial, municipal uses and distribution losses. The potential for modifying the recent past trend of increasing water consumption by water use conservation education programs, pricing policies, use of water-saving appliances, institutional restrictions and leak detection and maintenance programs was examined and discussed.

*Water Treatment Plant Study, Merrimack River, Massachusetts*, Hayden, Harding and Buchanan, Inc., March, 1975. This study determined necessary water treatment plant unit processes required to deliver a high quality drinking water supply utilizing the Merrimack River as a source. Construction and operating costs for various sized plants were developed and displayed.

*"An Investigation of Some Environmental Impacts for Possible Diversions of Flow from the Merrimack River."* Jason M. Cortell & Assoc. Inc., April 1975. This Study demonstrates that substantial diversions are possible from the Merrimack River without compromising proposed anadromous fish restoration programs. It specifies minimum flows in the River for each month of the year. When natural flows (or remaining flows) are below these quantities, water should not be diverted.

## **IV EASTERN MASSACHUSETTS—RHODE ISLAND METROPOLITAN AREA**

### **2 WASTEWATER REPORTS:**

#### **(A) BOSTON HARBOR**

*Technical Data Volume 3A, Study of Certain Industrial Wastes*, Jason Cortell, October, 1975. This volume reports on the identification and location of 27 types of industries. For each industry identified, the volume and constituents of the process wastes discharged are reported.

*Technical Data Volume 3B, Study of Wastes from Large Industries*, Jason Cortell, October, 1975. This volume reports on the identification and location of industries discharging 50,000 gallons per day or more of process wastes. For each industry located, the volume and characteristics of the discharged waste are reported.

*Technical Data Volume 5, Land Oriented Wastewater Utilization Concept*, Woodman and Howard, October, 1975. Reports on the formulation and design of a land application wastewater treatment system for the Eastern Massachusetts Metropolitan Area.

*Technical Data Volume 8, Urban Stormwater Management*, Corps of Engineers, New England Division, October, 1975. Reports on the quantity and quality of urban stormwater runoff in the Eastern Massachusetts Metropolitan Area. Also included is an array of alternatives for managing the stormwater together with costs and a projection of effects on the receiving items.

*Technical Data Volume 13, Impact Analysis and Evaluation*, Corps of Engineers, New England Division, October, 1975. Summarizes the identified impacts of wastewater management as discussed in Volumes 13A-13D and provides the evaluation required by Principles and Standards.

*Technical Data Volume 13A, Biological Impact Analysis*, Normandeau Associates, Inc., October, 1975. Reports the identified impacts of wastewater management concepts in the Eastern Massachusetts Metropolitan Area with particular emphasis on aquatic biological impacts.

*Technical Data Volume 13B, Socio-Economic Impact Analysis*, ABT Associates, October, 1975. Reports on the identification and analysis of impacts to the socio-economic environment of Eastern Massachusetts, resulting from wastewater management concepts.

*Technical Data Volume 13C, Hygienic Impact Analysis*, Corps of Engineers, New England Division, October, 1975. Discusses the effects on the public health of various wastewater management concepts.

*Technical Data Volume 13D, Visual, Cultural and Design Impact Analysis*, Woodman and Howard, October, 1975. Reports the effects of regional wastewater management concepts upon the visual-cultural environment and reports on the design implications of various facilities.

*Technical Data Volume 14, Public Involvement*, Corps of Engineers, New England Division, October, 1975. Reports on the Open Planning activities and results in the Boston Harbor-Eastern Massachusetts Metropolitan Area Wastewater Management Study.

## **(B) MERRIMACK RIVER**

*Open Planning/The Merrimack*, The New England Natural Resources Center, September, 1971. Presents a strategy for public involvement within the Merrimack River Basin.

*Aerial Remote Sensing Reconnaissance and Analysis of the Merrimack River Basin*, Coastal Research Corporation, March, 1972. Documents point source discharges into the Merrimack River and its major tributaries using remote sensing technology.

*Toxic Residual Elements and Compounds of the Merrimack River Watershed (Massachusetts Portion)*, Lycott Environmental Research Company, October, 1973. Estimates quantities and types of residual compounds, i.e., pesticides, discharged into the waters of the Merrimack River Basin.

*Appendix I-A, Geologic-Hydraulic Investigations*, Anderson and Nichols, Inc. and Goldberg-Zoino, Inc., November, 1974. Presents surficial and bedrock geology as well as groundwater hydrology data for the Eastern Massachusetts Area.

*Appendix I-B, Industrial Listings*, Anderson and Nichols, and Co., Inc. November, 1974. Lists various industries within study area and their estimated pollution contribution.

*Appendix I-C, List of Study Criteria and Instructions*, Corps of Engineers, New England Division, November, 1974. Lists various Federal and State Criteria and Instructions under which the study was accomplished.

*Appendix II Plan Formulation*, Corps of Engineers, New England Division, November, 1974. Shows processes of determining various technical alternatives and recommended plan.

*Appendix III, Volumes I & II, Design and Costs*, Anderson and Nichols, & Co., Inc., November, 1974. Presents engineering information designs and costs of each wastewater management alternative.

*Appendix IV Impact Analysis and Evaluation*, Corps of Engineers, New England Division, November, 1974. Summarizes various impacts contained in Volumes IV A, B, C, and D.

*Appendix IV-A, Socio-Economic Impacts*, ABT, Associates Inc., November, 1974. Describes the sociological and economic impacts of the wastewater management alternatives.

*Appendix IV-B, Volumes I & II, Biological Impacts*, Normandeau Associates, Inc., November, 1974. Presents terrestrial and aquatic biological data and information for the Merrimack Basin. Describes biological impacts associated with each wastewater management alternative.

*Appendix IV-C, Aesthetic Impacts*, Anderson and Nichols, and Co., Inc., November, 1974. Delineates the visual and cultural impacts of each wastewater alternative.

*Appendix IV-D, Hygienic — Public Health*, Corps of Engineers, New England Division, November, 1974. Presents water quality data and findings on magnitude of pollution from non-point sources. Discusses existing sanitary waste practices within the Basin and suggests needed changes.

*Appendix V, Institutional Arrangements*, ABT, Associates Inc., November, 1974. Describes existing authorities and management structures applicable to the study area and suggests modifications and changes that may be necessary to comply with the goals and requirements of PL92-500.

*Appendix VI, Public Involvement Program*, Corps of Engineers, New England Division, November, 1974. Lists public participation program for carrying out the study.

*Appendix VII, Comments*, Corps of Engineers, New England Division, November, 1974. Lists Federal, State and Local comments on the Merrimack River Report.

## V SOUTH CENTRAL PENNSYLVANIA STUDIES

*Preliminary Report: South Central Pennsylvania, Baltimore and Mason-Dixon Areas*, Corps of Engineers, North Atlantic Division, Baltimore District, February, 1970. An investigation of the urgent need areas of South Central Pennsylvania (York-Harrisburg-Lancaster) and Baltimore, and a preliminary analysis of the Mason-Dixon proposal.

*The Codorus Creek Wastewater Management Study*, Corps of Engineers, North Atlantic Division, Baltimore District, April, 1973. Outlines the alternatives which were developed to solve the water quality and related problems of the Codorus Creek Basin.

*Survey Report for Water Supply Development Alternatives*, Anderson—Nichols, August, 1974. This report is an investigation of the water supply situation in the five Urban Metropolitan Areas contained in the study area. Determinations were made of the magnitude and time of expected deficits in the UMA's and 13 alternative programs were investigated to determine engineering and cost solutions.

*Hydrologic Impact Studies of Alternatives to Meet Water Needs in South Central Pennsylvania*, Resource Analysis, Inc., September, 1974. This report investigated the hydrologic effects of alternative water supply development in the area. The impact on streamflow from ground and surface water withdrawals by the different alternatives were investigated through the use of a simulation model. Results include the distribution of out flows from the system and on tributaries for each alternative. Studies were also made to determine the surface water response to ground water withdrawals.

*Preliminary Assessment of Environmental, Social and Economic Impacts—Water Supply Development for the South Central Pennsylvania Area*, Roy F. Weston, Inc., September, 1974. This study is a preliminary assessment of environmental, social and economic impacts of the thirteen water supply alternatives for the study area. Analyses were conducted to determine beneficial or adverse effects from the point of view of these three disciplines, using categorical indicators and ranking systems.

*Preliminary Study of Legal, Institutional and Cost Sharing Arrangements for Water Supply in South Central Pennsylvania*, Booz, Allen and Hamilton, September, 1974. This study provides a preliminary analysis of possible legal, institutional, and cost sharing arrangements necessary to implement alternative water supply programs in the area. It assesses these arrangements for selected engineering alternatives and applies two institutional options to a regional program. The report also presents implementation plans for the new institutional arrangements required by the regional program.